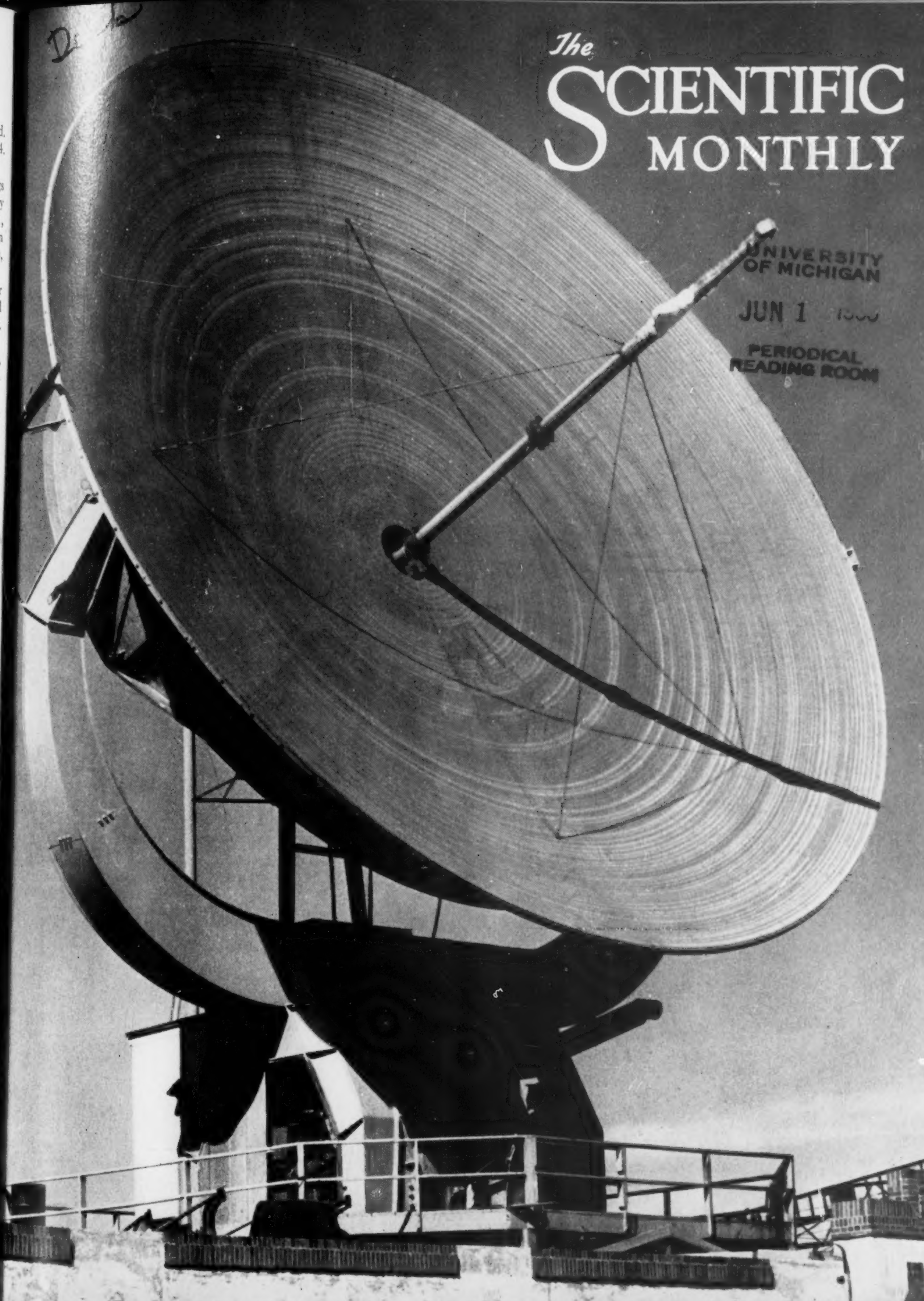
The SCIENTIFIC MONTHLY



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Index Issue

Cover: Naval Research Laboratory's 21-cm Antenna
[*Official United States Navy Photograph, see page 345*]

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Science and Technology

(From the month's news releases; publication here does not constitute endorsement.)

Laboratory Blocks

Sturdy, safe support at proper height for light or heavy pieces of laboratory apparatus such as beakers, flasks, ring stands, and so forth, can be obtained by the use of a new set of laboratory blocks. The blocks are made in 4- and 8-in. squares, both sizes in various thicknesses from 1/4 to 2 in. (Central Scientific Co., Dept. SM, 1700 Irving Park Rd., Chicago, Ill. Circular 1244.)

Projection Pointer

A new electric pointer that throws a bright arrow on the projection screen operates from a standard electric outlet. It is packed in a portable case that also contains a 12-ft cord, multiple-plug outlet, transformer, and low-voltage automotive lamp. (Ednalite Co., Inc., Dept. SM, Peekskill, N.Y.)

Rheometer

An instrument designed particularly for the measurement of the viscosity of small samples at high rates of flow, the new Castor-Severs microrheometer has a capacity of 0.7 ml and will handle samples as small as 0.1 ml. Temperature range is from room temperature to 300°C; pressure range is from 0 to 3000 lb/in.^{2} The instrument will determine viscosities from 1 to 5 $\times 10^9$ centipoises. During operation, air pressure is applied to a material chamber; the sample under test is timed and measured as it is extruded through a calibrated orifice. (Burrell Corp., Dept. SM, 2223 Fifth Ave., Pittsburgh 19, Pa.)

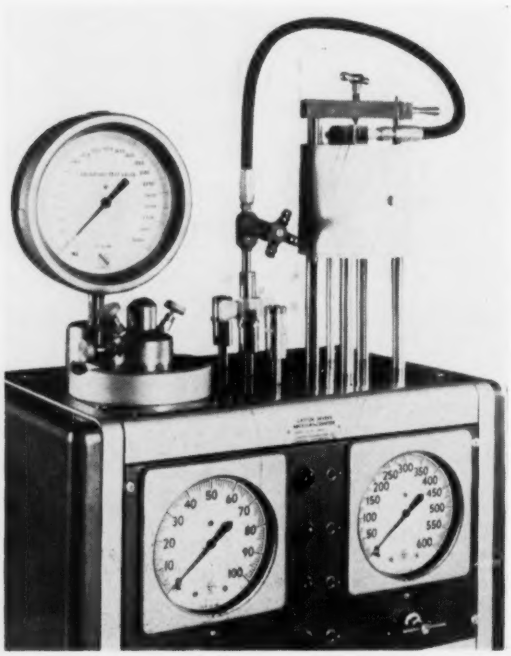


Table Saw Guard and Guide

A new transparent shield of shatter-resistant 1/2-in.-thick Plexiglas may be used to cover a circular saw. The shield allows visibility for many operations, including mitering, cross cutting, ripping, rabbeting, tenoning, dadoing, plowing, tonguing, template cutting, feathering, and diagonal sawing. The guard is designed so that it exerts a horizontal and downward pressure on the work. Other features are solid aluminum castings, steel supporting rods, and brass bushings. The guard can be set by means of a knob in any of three operating positions in extension plates attached to the table top. (Brett-Guard Co., Dept. SM, Englewood, N.J.)

Oil Filter

A permanent automobile oil filter has been made of porous bronze. The unit is cylindrical in shape and it is reported that the two models in production will fit nearly all American cars. An occasional rinse in gasoline is required to keep the filter clean. (Engine Products Manufacturing Co., Dept. SM, 5801 E. Beverly Blvd., Los Angeles 22, Calif.)

Reversible Electric Motors

Instantly reversible fractional horsepower motors have been announced by General Electric. Because there is no internal relay the motors can be reversed instantly from the external switch. A compact high-voltage capacitor helps start and reverse heavy loads. Ratings are either 115 or 230 v, 60 cy/sec, 1725 rev/min. Sizes available are 1/4, 1/3, 1/2, and 3/4 hp. (General Electric Co., News Bureau, Dept. SM, Schenectady 5, N.Y.)

Refuse Burner

Mounted on wheels, a new portable refuse burner is available in 6- and 10-ft^3 capacities. The unit is constructed of heavy gage steel; it has a perforated base to facilitate draft, and a steel ash collector 4 in. below the base. (Gardening Products, Inc., Dept. SM, 1502 State Highway No. 23, Wayne, N.J.)

Floor Tile Adhesive

Terraflex adhesive, developed for use with Terraflex vinyl-asbestos tile, is a colorless liquid that can be applied with a paint or whitewash brush. The new adhesive will bond the tile to concrete, plywood, unpainted plaster, asphalt-saturated asbestos felt, and other surfaces. Coverage is approximately 250 ft^2/gal. Troweling is not necessary. The adhesive is pressure-sensitive and retains its tackiness indefinitely. Smears can be removed with mineral spirits. (Johns-Manville, Dept. SM, 22 E. 40 St., New York 16.)

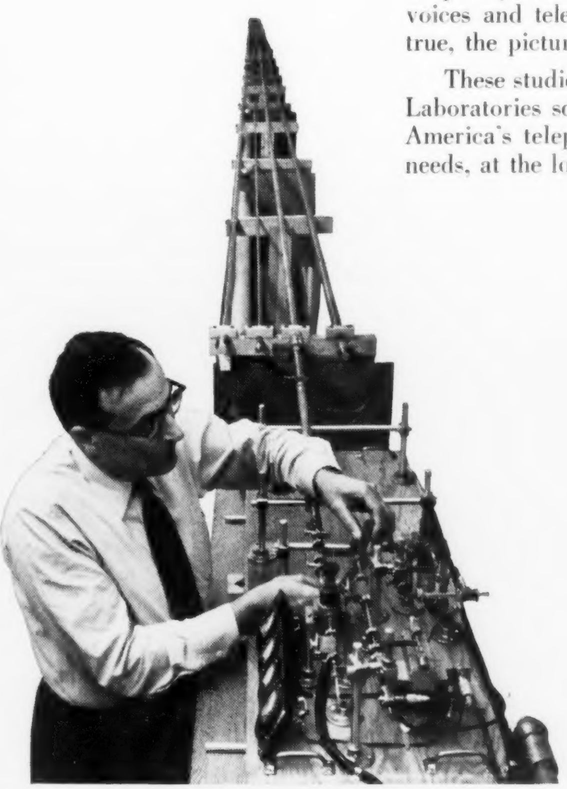
Pipes of Progress

Hundreds of thousands of telephone conversations or hundreds of television programs may one day travel together from city to city through round waveguides—hollow pipes—pioneered at Bell Telephone Laboratories.

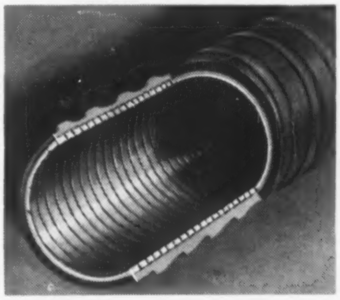
Round waveguides offer tremendous possibilities in the endless search for new ways to send many voices great distances, simultaneously, and at low cost. Today, Bell Laboratories developments such as radio relay, coaxial cable and multivoice wire circuits are ample for America's needs. But tomorrow's demands may well call for the even greater capacity of round waveguides.

Unlike wires or coaxial, these pipes have the unique property of *diminishing* power losses as frequencies rise. This means that higher frequencies can be used. As the frequency band widens, it makes room for many more voices and television programs. And the voices will be true, the pictures faithfully transmitted.

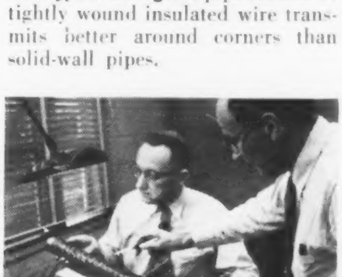
These studies illustrate once more how Bell Telephone Laboratories scientists look ahead. They make sure that America's telephone service will *always* meet America's needs, at the lowest possible cost.



Testing round waveguides at Bell Telephone Laboratories, Holmdel, New Jersey. Unlike coaxial cable, waveguides have no central conductor. Theoretically, voice-capacity is much greater than in coaxial cable.



New type of waveguide pipe formed of tightly wound insulated wire transmits better around corners than solid-wall pipes.



New type waveguide is bent on wooden forms for study of effect of curvature on transmission. The waveguide itself is here covered with a protective coating.

Bell Telephone Laboratories

Improving America's telephone service provides careers for creative men in scientific and technical fields.

THE SCIENTIFIC MONTHLY

JUNE 1955

New Science of Radio Astronomy

BART J. BOK

Dr. Bok is Robert Wheeler Willson professor of astronomy at Harvard University and codirector of the Radio Astronomy Project at the George R. Agassiz Station of Harvard Observatory. He was educated at the universities of Leiden and Groningen in Holland and came to Harvard in 1929. In 1950–51 Dr. Bok spent 18 months in South Africa studying the Milky Way. He is author or coauthor of three books on astronomy. The following article is based on Dr. Bok's vice-presidential address before Section D of the AAAS at Berkeley, 29 December 1954.

BEFORE the advent of radio astronomy, all of our knowledge of the physical universe of stars and galaxies had been obtained from analyses of a relatively narrow range of wavelengths. Until a few years ago, it was not possible, because of atmospheric absorption, to study by optical methods radiations from the sun and stars with wavelengths less than 3000 A. Rocket research has made it possible to send relatively simple apparatus to high altitudes and thus obtain observations in the violet to 1000 A, but we shall probably have to wait for the days of the "space platform" before we will be able to make extensive studies of this radiation. Thermocouples and other heat-measuring devices—as well as remarkable developments in infrared-sensitive photographic emulsions—have made it possible to reach beyond the visible red spectrum into the heat spectrum, but our earth's atmosphere absorbs radiation so heavily in these regions that relatively little information has been obtained concerning radiations with wavelengths in excess of 30,000 A. Our basic range of available frequencies for optical research does not extend much beyond the 1000- to 30,000-A range, which means that most of our knowledge about the universe has come from studies of not more than 5 octaves of the electromagnetic spectrum. Since the first discovery of radio radiation from the Milky Way in 1931 by Karl G. Jansky of the Bell Telephone Laboratories, it has been found that radio radiation can actually be recorded for the entire range of wavelengths between 1 cm and 30 m, a total range of roughly 12 octaves of the electromagnetic spectrum.

To record and study the radio radiation reaching us from outer space, we require very large antennas and sensitive electronic recording apparatus. Let us first consider briefly the antenna problem. In our first course in optics, we learned that the performance of a mirror depends upon the size of the mirror and on the precision of its surface. Optimum performance can generally be guaranteed if the mirror's surface agrees to within ¼ wavelength with the desired geometric figure. Size of the mirror is important in two ways, since size not only controls the limiting brightness for the faintest object within reach but also determines the smallest angular detail that one may hope to resolve. For radio studies, we require large paraboloid antennas, first,

because the radio radiation is weak, and we need to squeeze all we can get into a small point at the focus; and, second, because the angular resolution of a paraboloid antenna depends only upon the aperture of the antenna expressed in terms of the wavelength of the radiation that one studies. A 60-ft antenna used for the study of the 21-cm radiation from our galaxy will resolve detail in surface features only of the order of a little less than 1 deg. Since ¼ wavelength is here about equal to 2 in., the tolerances of the reflector's surface in all positions should not exceed this amount.

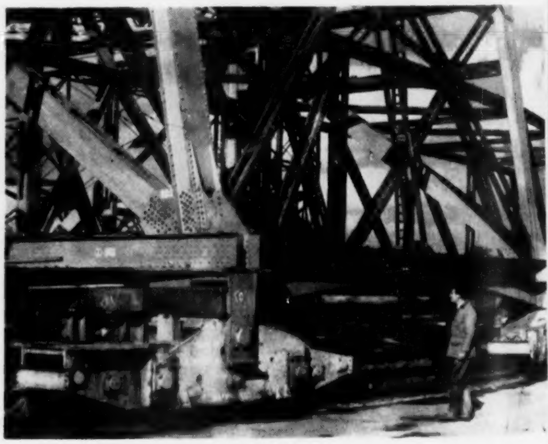
The need for large antennas was first realized clearly by the pioneer investigator Grote Reber, who, in 1937, with very little outside support, built at his home in Wheaton, Illinois, a 31-ft parabolic antenna. The largest radio mirror now in operation in the United States is the 50-ft paraboloid of the Naval Research Laboratory in Washington, D.C. With the support of the National Science Foundation, Harold I. Ewen and I and our associates at the George R. Agassiz Station of Harvard Observatory are undertaking the construction of a 60-ft steerable antenna, and a similar instrument is on order for the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Two larger parabolic antennas are now being built, one a 75-ft paraboloid for use by the Dutch radio astronomers, the other the giant 250-ft paraboloid for the Jodrell Bank Station of the University of Manchester in England. I do not wish to give the impression that large paraboloids are the one and only solution to all problems in radio astronomy, but before we return to problems of instrumentation, let us first consider briefly how far the science of radio astronomy has advanced in its several departments.

The Radio Sun

The sun was not discovered as a source of radio radiation until 1942, and the detection of the radiation at that time, coming as it did almost as a by-product of wartime radar research, may almost be termed accidental. The art of electronics has, however, advanced so rapidly during the past 15 years that the radio sun now represents one of the most accessible objects for study over the entire range of wavelength. It is an exceedingly strong emitter at wavelengths of the order of ½ m and greater, but even at shorter wavelengths its radiation is sufficiently strong at present to permit careful and detailed study. The radiation output of the sun in the radio range is far from constant. We recognize that the lowest level of radiation output at most wavelengths is that of the "quiet sun," and it has indeed been fortunate that careful studies of the radiation base have been made during the unusually peaceful minimum of activity in the 11-yr solar cycle through which we have just passed. At times of solar activity, all sorts of disturbances occur that produce enhanced radio radiation of the sun.

Now that we are gradually moving toward an increase in all kinds of solar activity associated with the 11-yr cycle, we may expect to observe with growing frequency the radio "noise storms" that accompany the passage of large sunspot groups across the the solar disk. "Radio outbursts" and "isolated bursts," some of them associated with visible solar flares, others without any visible means of support, should again become the order of the day. Perhaps the most striking aspect of this variable solar radiation at radio wavelengths is the extreme range of its variability, which, at some wavelengths, may amount to a factor as large as 1 million. This variability is far greater for meter wavelengths than for wavelengths of 50 cm and less.

We have known for many years that variability of the sun's radiation has important effects upon the earth, especially upon the atmosphere of the earth. It now appears that in the records of variation of radio radiation from the sun, we have potentially one of the finest barometers for the study of solar variability. Since new and refined techniques of observation have become available in recent years, it is now possible to localize the sources of specific disturbances on the sun's surface or in its atmosphere. Through the combined study of radio and optical



A portion of the mounting for the 250-ft steerable paraboloid at the Jodrell Bank Station of the University of Manchester. The photograph shows the movable base of one of the pair of vertical towers that will carry the large parabolic antenna, which is scheduled to be in operation late in 1955.

E-W and N-S Solar interferometers at the radio observatory in Sydney, Australia. The E-W interferometer produces a narrow scanning beam with its long dimensions vertical, or not too far from vertical. The N-S interferometer produces a narrow beam that runs horizontal, or not too far from horizontal. The instrument is used principally for studies of variation of brightness over the solar disk. The water reservoir just happens to be there and is not used in the system.

effects, we may hope to gain insight into the origin of these disturbances, and from these, in turn, should follow an approach to an understanding of their effects upon the earth and its atmosphere. At several radio observatories, the study of the radio sun is now the primary research project. Outstanding work is currently being done at the radio observatory in Sydney, Australia; at the two major radio centers in England, Manchester and Cambridge; at the Naval Research Laboratory and Cornell University in the United States; by A. E. Covington in Canada; and by groups in France, Belgium, and Japan. The most revolutionary apparatus has been built in Australia under the direction of E. G. Bowen and J. L. Pawsey. W. N. Christiansen and his associates are operating near Sydney two very high resolution interferometer arrays of small radio mirrors, and J. P. Wild and his group have a rapidly scanning radio spectrometer. The Christiansen apparatus permits the very precise localizing of sources of excess radio radiation on the sun; and, with the Wild apparatus, one obtains an almost continuous picture of the brightness distribution in frequency of any disturbance on the sun.

At wavelengths of the order of 1 m and greater, the sun is subject to terrific variations in radio brightness. The radio radiation in the meter-wavelength range is produced mostly in the sun's corona, and the radiation from the quiet sun is already sufficiently strong to be indicative of temperatures in the million-degree range in these outer parts of the sun's atmosphere. Increases in the noise level of the sun by a factor of 1000 over that of the quiet sun have been observed, and here one should bear in mind that quite often the increase can apparently be localized on small areas in the sun's atmosphere. It seems most unlikely that this enhanced solar radiation is of thermal origin. The coming sunspot maximum promises a gradual increase in activity in the radio range; and, with the new equipment now at hand, great advances in interpretation of solar radio phenomena are bound to come within the next decade.

At the shorter wavelengths, the sun is a relatively constant radiator, and here more and more

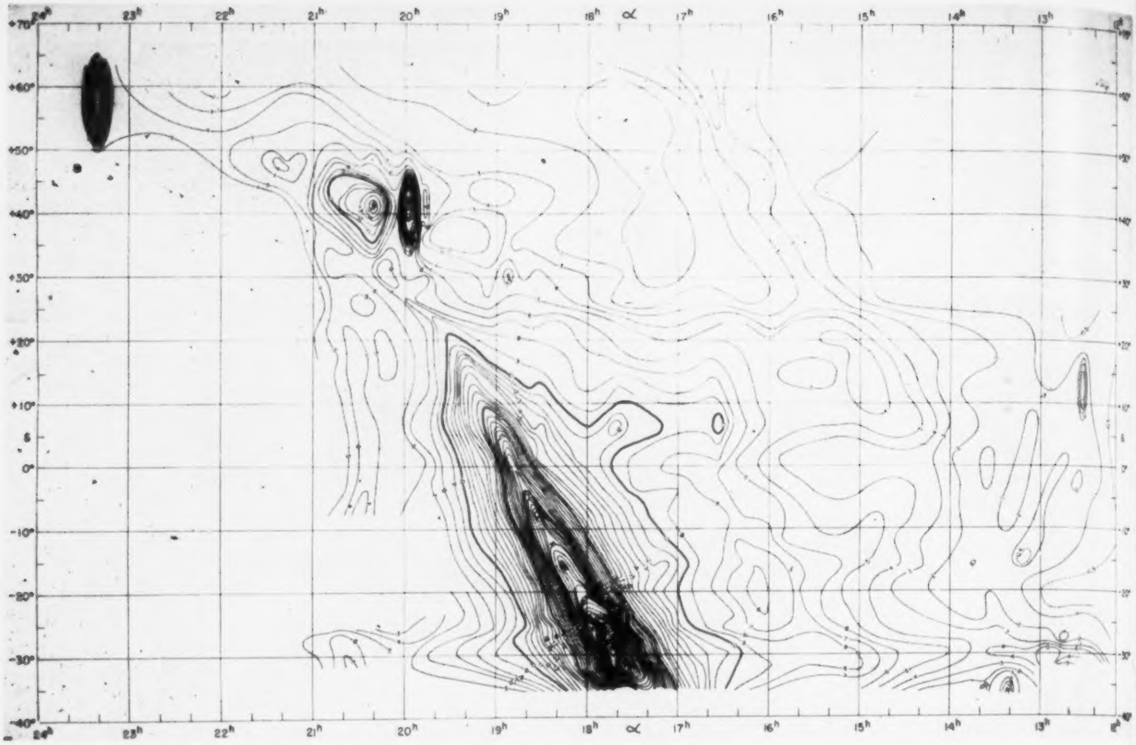


Fig. 1. Results of the Ohio State University survey. Kraus and his associates have studied the brightness distribution over the sky at a frequency of 250 Mcy/sec. The lines shown are contours of equal surface brightness. The greatest intensities are found for the direction of the center of our galaxy, located below the center of the map. The black ovals in the upper left-hand corner are the discrete radio sources in Cassiopeia and in Cygnus.

attention is being given to the study and interpretation of brightness distribution over the disk. All sorts of techniques have been employed to study the variation of brightness with distance from the center of the sun's disk. In England, at Cambridge and at Manchester, interferometric studies showed some time ago that the sun's surface appears to be of by no means uniform brightness. Furthermore, eclipse observations have shown that some of the radiation reaching us comes from well above the layers of the photosphere—from the upper chromosphere and even the lower corona. John P. Hagen and Fred T. Haddock at the Naval Research Laboratory in Washington have done some of the finest work in this field.

Until a few months ago, it seemed that there would be at least radial symmetry in the brightness distribution over the sun's surface. This illusion has been rudely shattered by the recent provisional results announced by Christiansen and his associates. Evidence now exists that, at wavelengths near 21 cm, the continuous radiation of the sun varies along the sun's equator in quite a different fashion from that along a radius from center to pole. It will be exceedingly interesting to watch developments in the years to come and to see to what extent the character of these variations with latitude on the sun remain unchanged during the coming period of increased solar activity.

Discrete Sources and Continuous Background

The first complete surveys of the radio radiation from the Milky Way and beyond were those begun in 1939 and completed in the early 1940's by Reber. After the war, in 1947, J. S. Hey, J. W. Phillips, and S. J. Parsons in England published a sky survey at 4.7-m wavelength. Several other surveys have been made since then, notably the recent one, at 120-cm wavelength, by J. D. Kraus at Ohio State University (Fig. 1). In all these surveys, the band of the Milky Way appears as the most clearly marked phenomenon, and the great strength of the radio radiation reaching us from the direction of the center of our galaxy is a characteristic feature of all isophotic maps. In addition to the radiation attributable to some variety of discrete source or sources of radio radiation associated with our Milky Way system, we observe a general background component coming to us presumably from far beyond the borders of our own galaxy. Other galaxies combine to produce much of this background component, and Kraus has shown that

there is evidence for radiation from clusters of galaxies possibly originating in part in the spaces between the galaxies.

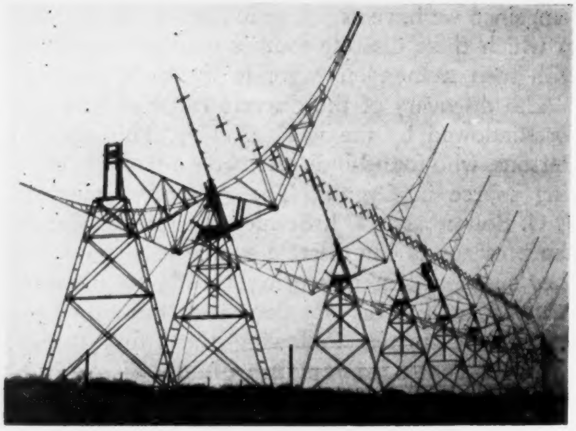
We are beginning to understand the origin of the continuous radiation from our own galaxy at centimeter wavelengths. The studies by Hagen and Haddock and their associates at the Naval Research Laboratory in Washington have revealed that enhanced continuous radiation reaches us from the direction of some of the best-known optical emission nebulae. This radiation almost surely comes from free-free transitions in ionized hydrogen clouds; that is, it is produced as a by-product of fleeting encounters between hydrogen nuclei, the protons, and free electrons. Even before it had been observed, the probable presence of the short-wave continuous radiation had been predicted by J. L. Greenstein of the California Institute of Technology.

The chief puzzle that remains today is just why this radiation at wavelengths of 50 cm and less should be so very strong from the general direction of the center of our galaxy, since offhand we do not associate excessive amounts of ionized hydrogen with the nuclear regions of galaxies. The discovery by the NRL group of one or more strong discrete sources at centimeter wavelengths in precisely the direction of the galactic center shows that ionized hydrogen does exist near or at the center of our galaxy. Perhaps our galaxy has something in common with the galaxies studied several years ago by C. K. Seyfert and R. Minkowski, who noted the presence of strong emission lines near the centers of several galaxies; this observation suggests that conditions near the center of these galaxies are not unfavorable for the production of radio radiation by free-free transitions.

There are at present several theories to explain the origin of the continuous radiation at meter wavelengths, but to date none of them seems really satisfactory. Thermal radiation of the type we suspect at shorter wavelengths cannot be considered to be the principal source, since the brightness temperatures for the continuum in the meter range point to equivalent black-body temperatures of the order of 1 million degrees Kelvin, far in excess of known interstellar temperatures, which do not rise much above 10,000°K. The origin of continuous radiation in the meter range is at present sought mostly in an agglomeration of thousands upon thousands of faint "radio stars," or at least in discrete and relatively small sources, distributed somewhat in the manner of the stars of Population II (although *not* the known optical stars of Population II). These suggestions have considerable merit, but they do not really go to the heart of the problem, since we have as yet no inkling of the manner in which these discrete sources manage to radiate with such tremendous vigor in the radio range.

The discovery of the discrete radio sources was foreshadowed by the work of Hey, Phillips, and Parsons, who found indications for a strongly emitting source in Cygnus. The Australian scientists J. G. Bolton and G. J. Stanley not only confirmed the presence of the discrete source in Cygnus, but they succeeded in measuring (1948) its diameter with accuracy. This was done with the aid of the sea interferometer. Following these first studies, the field developed rapidly with the discovery of many fainter sources. In England, M. Ryle and his associates, D. D. Vonberg and F. G. Smith, in Cambridge and R. Hanbury Brown and associates at Jodrell Bank had developed other interferometer techniques; at the same time Hanbury Brown had constructed his fixed 218-ft paraboloid. Bernard Mills in Australia extended the earlier surveys, and he and Smith measured with high precision the positions of the brightest discrete sources. In the past few years, research on discrete sources has developed beyond the dreams of all but the most venturesome. Ryle and his associates have built a beautiful interferometer array, with four major components with a light-gathering power (in Ryle's words) "of 1 acre," which promises to yield soon a published list of 1750 specific discrete sources. In Australia, Mills is operating an even more revolutionary type of instrument, the Mills Cross, which produces a pencil beam subtending a very small

Emission nebulae of the southern Milky Way. Some of the large clouds of ionized hydrogen can be observed along most of the band of the Milky Way. They derive their luminescence from the presence of very hot stars, rich in ultraviolet radiation, which are either imbedded in the nebulosity or close to it. The photograph was taken with the 60-in. Rockefeller reflector of Boyden Station.



Cavendish Laboratory interferometer. One of the four units that comprise the interferometer array used by Ryle and his associates at Cambridge, England, in the preparation of a catalog of 1750 discrete sources.

solid angle. The first Mills Cross in the United States is now in operation at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington.

A wholly new series of problems presents itself when we turn to the identification of the discrete radio sources with optically observed objects, a subject in which we owe much to the researches of Minkowski and W. Baade, of the Mount Wilson and Palomar Observatories. The most striking fact discovered is that very few of the conspicuous stars and nebulae of our Milky Way system are among the recognized objects in the radio sky. The brightest discrete source within our Milky Way system is that in Cassiopeia, which has at its position in the sky some highly turbulent emission nebulosity, which is far from striking even on the Palomar-Schmidt photographs. The brightest discrete source that is placed outside our Milky Way system is that in Cygnus; it results apparently from the collision between two galaxies, presumably about 200 million light-years away! Number 3 on the list is an old acquaintance, the Crab Nebula in Taurus, the product of an ancient supernova explosion and now a highly turbulent gas mass. Other sure identifications are mostly with single galaxies, some of which have highly peculiar features, pairs of galaxies in collision, or at least interacting with each other, and groups of galaxies.

The definite identification of a discrete source presents very difficult problems to the optical astronomer and the radio astronomer alike. In many cases the optical manifestation corresponding to a discrete source at radio wavelengths is elusive and faint and very difficult to observe. Since we are dealing with optically very weak objects, we must have very accurate positions for the discrete sources before we can hope to start work on the identification. At present the required accuracy is lacking for all but the brightest radio sources, and the problem is further complicated by the "ghosts" of radio astronomy, the side-lobes of instrumental patterns that often confuse the radio astronomer. The application of widely differing techniques for the detection of discrete radio sources is highly desirable, since the pattern of side-lobes is very different for Ryle's wonderful multiple interferometer, for the Mills Cross, and for Kraus' knife-edge antenna with its helices. By the use of a variety of techniques, and with everlasting emphasis on high precision in the measurement of positions, we may count on slow future progress in identification, but at best the path will be a difficult one to travel.

The 21-cm Line of Neutral Hydrogen

The first phase in the development of a new branch of science is often one in which single spectacular discoveries are made, every one of them of real value for its own sake, but most of them not intimately related to developments in neighboring areas of scientific research. In the second phase, the new science becomes an integral part of a group of related scientific fields, and it contributes to the solution of scientific problems that are amenable to study by a variety of approaches.

Radio astronomy is slowly passing from the first to the second phase. We are seeing this happen in solar research, where the radio data, properly blended with optical data, are providing us with a fresh approach to the study of solar activity and are giving us new insight into conditions in the sun's atmosphere. In the meter-wavelength range, the discrete radio sources are still an enigma, but

Mills Cross of the radio observatory in Sydney. Mills and his associates have constructed an array with an over-all length of 1500 ft, which, at a wavelength of 3.5 m, receives a cone with an angle of ¾° at one setting.

identification with optical objects has progressed to the stage where we realize that here we are dealing with phenomena associated with highly turbulent gas masses. In the centimeter and decimeter range, radio and optical studies of emission nebulae are already proving to be different ways of studying the effects of free-free transitions in ionized gas clouds. In no other area, however, has the blending progressed as far as in the study of the 21-cm radiation from neutral hydrogen. The investigator of 21-cm features cannot possibly disentangle the confusion of his radio data without repeated reference to the results of optical research, and apparently the time has come in which the optical Milky Way astronomer must be thoroughly aware of the work of his colleagues in the radio field if he wishes to make headway in the interpretation of optical data.

The romantic story of the prediction and discovery of the 21-cm line of neutral hydrogen has now been told several times, but it bears repeating. In 1944, H. C. van de Hulst, of Leiden, Holland, predicted in a wartime astronomical colloquium in occupied Holland that it might be possible to detect the 21-cm radiation originating in the clouds of neutral hydrogen of our galaxy. This radiation was detected in March 1951—four short years ago!—by Ewen and E. M. Purcell of Harvard University, and their discovery was confirmed promptly by radio groups in Holland and in Australia. The radiation originates in a transition between the two hyperfine levels of the Lyman level of the neutral hydrogen atom; the energy of the hydrogen atom is slightly greater when the spins of the nucleus and the electron are parallel than when the spins are antiparallel. The 21-cm line appears in emission as a result of transitions from the higher level of parallel spins to the lower level of antiparallel spins; an absorption results from a transition in the opposite sense.

It is interesting to reflect that before the days of 21-cm research, we had no way of confirming by direct optical observation the existence of extended interstellar clouds of neutral hydrogen. It is true that the Balmer lines of neutral hydrogen are observed in emission in the spectra of most diffuse nebulae, but it has long been known that these emission lines result as a by-product of the recombination of a free electron and a proton; in a cloud of ionized hydrogen, a free electron is captured in one of the higher quantum number orbits of the neutral atom, and the just-formed neutral atom has the excited electron cascading promptly to the lowest, or Lyman, level, emitting a Balmer quantum on the way. The clouds of hydrogen in which these processes take place are basically clouds of ionized hydrogen, for there simply would not be enough excitation energy available in a predominantly neutral cloud to lift a perceptible fraction of the atoms to the levels with quantum numbers 3 or higher and thus permit emission of a Balmer quantum by the cascading process just described. The optical researches of Baade of Mount Wilson and Palomar Observatories and of W. W. Morgan and his associates at Yerkes Observatory had already shown conclusively that the clouds of ionized hydrogen are observed only along the spiral arms of galaxies; and, although one could surmise that the neutral hydrogen clouds would fill the remainder of the spiral pattern, no definite proof of this assumption could be given before the days of 21-cm research. This situation has changed as a consequence of recent radio-astronomical studies.

Three years ago, J. H. Oort and his associates began their epoch-making researches into the spiral structure of our own galaxy for the sections that can be studied from the northern latitude of Holland (Fig. 2). They have found evidence for three clearly marked sections of major spiral arms; the first, known as the Orion arm, in which our

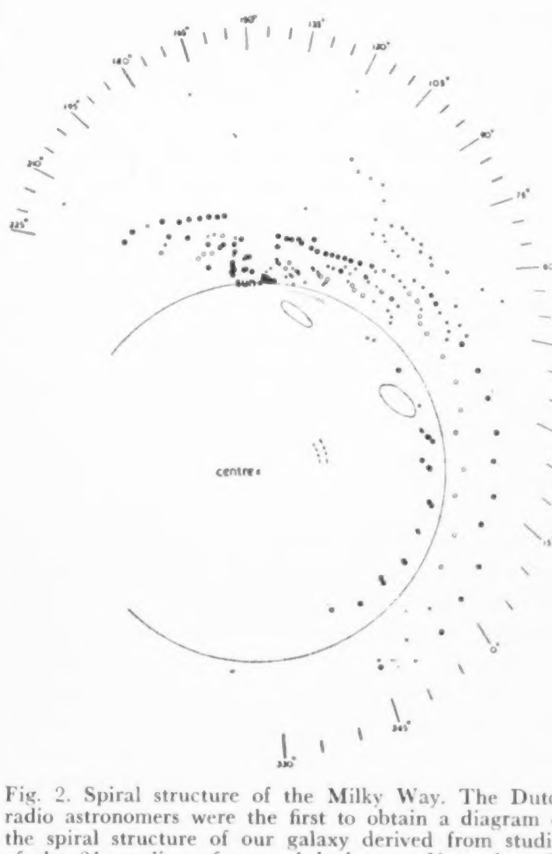


Fig. 2. Spiral structure of the Milky Way. The Dutch radio astronomers were the first to obtain a diagram of the spiral structure of our galaxy derived from studies of the 21-cm line of neutral hydrogen. Note that the spiral pattern is revealed to distances far beyond the distances to the center of our Milky Way system.

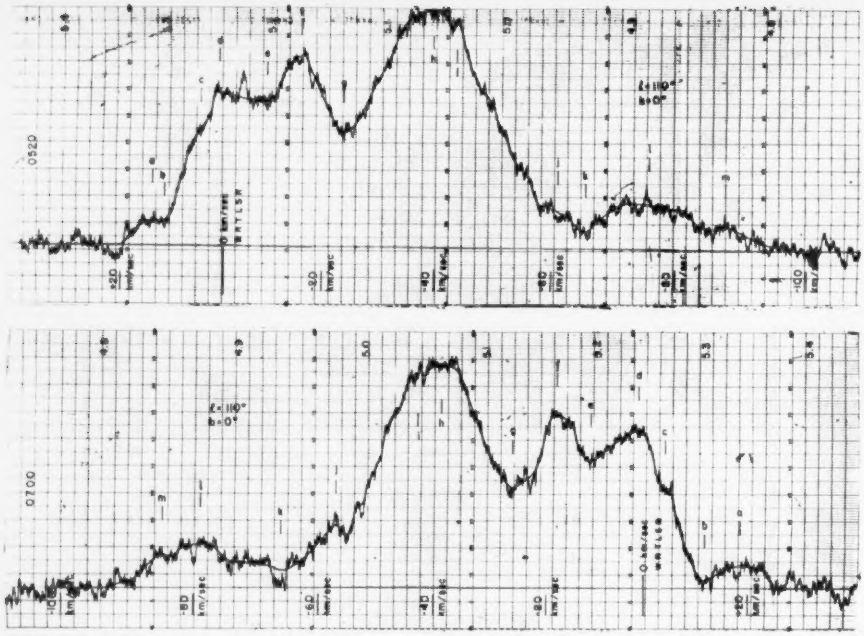


Fig. 3. Two 21-cm profiles obtained with the Agassiz Station radio telescope. These profiles are taken in the order upper first, lower second. The horizontal scale represents the frequency, which is readily transferred to radial velocity, of a approach (−) or recession (+) of the cloud responsible for the radiation in question; the intensity of the radiation at each frequency is recorded on the vertical scale. The maxima of intensity refer to features related to the spiral structure of our galaxy.

sun is located; the second, the Perseus arm, so named after its most conspicuous stellar component, the double cluster in Perseus; and the third, an as yet unnamed arm still farther from the center of our galaxy than the Perseus arm. It should be noted that sections of the Orion arm and of the Perseus arm had already been discovered by Morgan and his associates, but the Dutch radio researches showed that the Perseus arm could probably be traced to well beyond the center of our galaxy. By optical methods, it had been found possible to detect traces of spiral structure in our own Milky Way system to distances from our sun to 3000 parsecs, and even a bit more, but no one could have dreamed before the days of 21-cm research that it would become possible to detect with relative ease elements of spiral structure of our own galaxy to distances as great as 12,000 to 15,000 parsecs from our sun.

The secret of the success of the Dutch investigators lies in the fortunate circumstance that the dense dust clouds of our galaxy, which cut off our optical view of the more distant elements of spiral structure, transmit undimmed the 21-cm radiation reaching us from great distances. In the course of the past year, the Australian radio astronomers F. J. Kerr and J. V. Hindman have extended the Dutch survey so that both the Northern and Southern Hemispheres have now been studied. The preliminary map of spiral structure given by Kerr and Hindman supplements the picture provided for us by the Dutch group and shows conclusively that there is much spiral-like structure in our own galaxy, at distances from the galactic center between 20,000 and 40,000 light-years—that is, for distances from the galactic center comparable to the distance from our sun to the center. Considerable neutral hydrogen is also present in the inner parts of our galaxy, but here further detailed studies—preferably to be undertaken with radio telescopes of far greater aperture than those available at the present time—are required before the complex central structure may be disentangled.

During the next few years it should be possible to study from carefully planned regional surveys the detailed features of the spiral structure of our galaxy. The Dutch radio astronomers have already undertaken a second survey in which the centers for the study of the 21-cm line are much more closely spaced than in the first survey. Detailed regional surveys are now in progress at the Agassiz Station of Harvard Observatory and at the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Thomas A. Matthews, who has been observing at the Agassiz Station, has recently studied the detailed spiral structure of our galaxy exhibited by the section of the Milky Way from Lacerta and Cepheus through Cassiopeia to Perseus (Fig. 3). While there is evidence of considerable turbulent motion in the hydrogen clouds, there are also some marked cases of bifurcation of spiral arms. It is cheering to note that the groups and associations of hot stars—which traditionally are found to follow very closely the spiral pattern of galaxies—reveal indeed a pattern

not unlike that of the neutral hydrogen. The small clouds that produce the remarkable multiple stellar absorption lines found by Guido Münch, of the California Institute of Technology, also fit very well into the structural pattern found by Matthews. At the Department of Terrestrial Magnetism, H. L. Helfer and H. E. Tatel are engaged in studies of a similar nature, and there is good agreement between results of observations of centers in common among the several radio surveys.

In the regional surveys to which I have just referred, we find that the radio astronomer cannot analyze his material properly without constant reference to the results obtained by the older methods of optical astronomy, and *vice versa*. This blending of the two techniques of optical and radio astronomy is perhaps seen equally well in the studies dealing with the gas constituent of large complexes of cosmic dust and the somewhat smaller clouds of dust known as dark nebulae. The problem of whether or not concentrations of cosmic dust are also proportionally great concentrations of interstellar gas has for some years loomed large in optical astronomy. It has become apparent from theoretical studies that the dust clouds of our Milky Way system may well mark locations where the formation of new stars is under way, and it is obviously important to decide how much gas is present relative to the dust in one of these dense dark nebulae; the predicted course of evolution of a dark nebula is necessarily dependent upon the answer to this question. It seemed impossible to settle this question by optical research, but through the new techniques of radio astronomy we seem to be heading toward a solution.

About a year ago, A. E. Lilley decided to use the Agassiz Station radio telescope in a study of the 21-cm radiation from the Taurus dark nebula complex and surroundings (Fig. 4). He found that the strength of the 21-cm signal increased markedly as he measured, starting first at a position in the sky well outside the limits of the dark complex, and then gradually moving to positions closer to the apparent boundary of the complex, making sure at all times that his positions were spaced at a constant angular distance from the central band of our Milky Way. A signal of fairly uniformly high intensity was then received from all positions at comparable distance from the galactic circle inside the complex, but Lilley found that the signal decreased again in strength as he passed to positions beyond the outer edge of the complex. In other words, Lilley could show by his observations that the known concentration of cosmic dust in the complex is accompanied by a concentration of neutral hydrogen gas. So far, so good. But do the very densest dark spots inside the dark nebulae complex exhibit the further increase in signal strength of the 21-cm radiation that one might expect, if gas and dust were found everywhere in precisely the same proportion? Lilley's results did not permit us to answer this question unequivocally, and further special research was obviously necessary. My associates, R. S. Lawrence and T. K. Menon, and I took the next step: again with the aid of the Agassiz Station radio telescope, we compared the signal strength for two very dark centers in the Taurus complex and one very dark center in the Ophiuchus complex with the signal strength of neighboring, far less obscured areas of the sky. The result of this recent investigation confirms the preliminary result obtained last year by the Dutch radio astronomers: the very densest dark spots do not show the expected increase of 21-cm signal strength that should occur if cosmic dust and neutral atomic hydrogen were present everywhere in the same proportions. In future studies we shall have to consider more seriously than we have in the past the probable evolutionary development of relatively small dark nebulae without a very great gaseous component.

One might ask: Why should we get so worked up about a possible gaseous admixture in our clouds of cosmic dust? The answer to this question is that the role that the gas plays in a dust complex as a whole is by no means very small. According

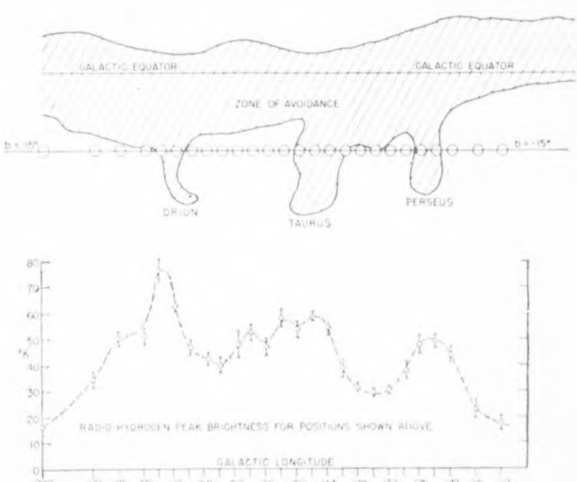


Fig. 4. Relationship between interstellar gas and dust. In the upper half of this diagram by Lilley is the outline of Hubble's "Zone of avoidance"—which delineates the areas of high interstellar dust concentration—for the section between galactic longitudes 100° to 200°. The line at galactic latitude, $b = -15°$, marks the positions for which the intensity of the 21-cm radiation was measured; the resulting "peak brightnesses" in degrees Kelvin are plotted below. This diagram shows that the strongest 21-cm radiation reaches us from the direction of the greatest dust concentration.

to Lilley, the average value for the ratio between the density of the gas and that of the dust inside a complex is of the order of 100. The techniques of radio astronomy have provided us with a clear-cut answer to the problem of the presence of neutral atomic hydrogen in dark nebulae complexes and individual clouds of cosmic dust; there is an excess of neutral atomic hydrogen in the large complexes, but the densest spots of cosmic dust in the dark nebulae complex have no more than an average hydrogen gas content. There still remains with us, however, the problem that molecular hydrogen may be abundant, especially in the densest small dark nebulae. For the present, neither radio nor optical techniques can give us any information regarding the presence or absence of molecular hydrogen; and, for the time being, we shall have to return to pure theory and speculation in considering the pros and cons for interstellar hydrogen molecules.

A fascinating array of novel problems presents itself when we consider the 21-cm radiation that reaches us from the direction of the center of our galaxy. An extensive general survey of the 21-cm line profiles for the direction of the galactic center and the entire surrounding section has been made by D. S. Heeschen, again using the equipment at Agassiz Station. The observed profiles, in which the measured brightness temperature is plotted against frequency (which corresponds to radial velocity of approach or recession), show a simple Gaussian character for positions some degrees away from the precise direction of the galactic center; but, for directions near that of the center, double-peaked curves appear, which indicate either contributions from multiple-cloud systems, or self-absorption caused by differences in temperature along the line-of-sight.

This particular section of the Milky Way is being studied in great detail, and very effectively, by Hagen and his associates at the Naval Research Laboratory in Washington, D.C., where the great 50-foot antenna is in operation. The first important result was announced in 1953 when Haddock, C. H. Mayer, and R. M. Sloanaker told of the discovery of a strong discrete source in the direction of the galactic center and observed at a wavelength of 9.4 cm. A few months later, Hagen, E. F. McClain, and N. Hepburn studied the same region of the sky in the continuum just outside the 21-cm line and confirmed the presence of strong radiation from the precise direction of the center of our galaxy. During the summer of 1954, McClain investigated further the profile of the 21-cm line of the galactic center, using the highest resolution attainable. The result is a profile with at least three remarkable absorption features, indicating the presence of several relatively small, but very dense, absorbing clouds of neutral hydrogen between our sun and the source of continuous radiation at the galactic center itself.

The studies by Hagen and his associates have raised the important question of possible absorption effects produced by small clouds of neutral hydrogen in the spectra of remote discrete sources of continuous radio radiation. The first very remarkable result has just been announced by Hagen, Lilley, and McClain. The famous discrete source in Cassiopeia, which is now readily detectable as an emitter of fairly strong continuous radiation in the vicinity of the 21-cm line, shows at the wavelength range of the 21-cm line three distinct and very sharp absorption features. These must be produced by small and compact, but very dense, clouds of neutral hydrogen (Fig. 5), reminiscent of the sharp absorption features noted by Münch in his studies of the interstellar K and D lines by optical methods. With the discovery of these unusually sharp absorption features, Hagen and his group have opened up a new era in radio research.

Our present equipment is not yet sufficiently sensitive to detect this 21-cm radiation for

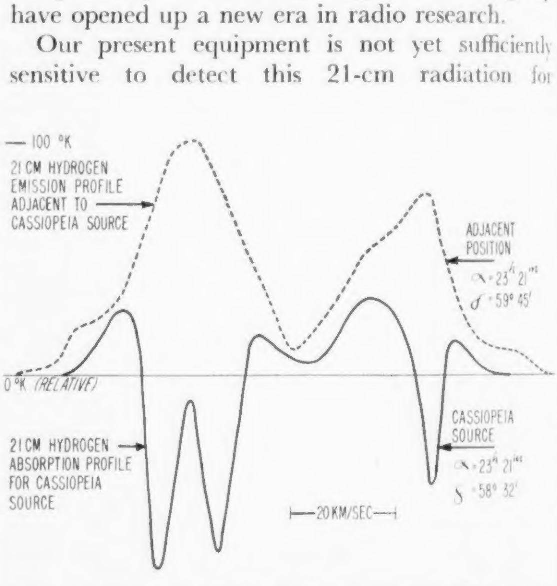
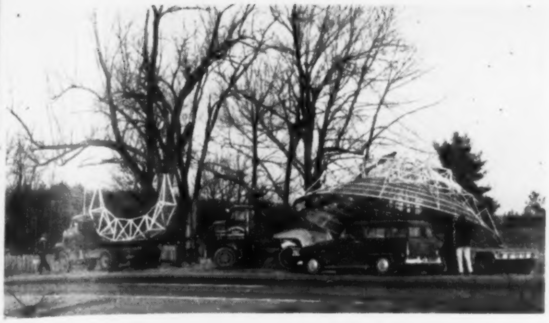


Fig. 5. Absorption effects in 21-cm profiles. This graph, which was prepared at the U.S. Naval Research Laboratory, shows the marked effects produced by absorption from small interstellar clouds of neutral hydrogen. In the upper half of the diagram, there is a typical profile for a region in Cassiopeia; the two peaks suggest the presence of two spiral arms for that particular field. The lower half of the diagram shows the profile for the discrete source in Cassiopeia. Here the radiation from the source is so strong that the radiation from the surrounding areas is of little importance. We observe radiation from the discrete source with three marked absorption features produced by individual clouds of neutral hydrogen located between the sun and the discrete source. These absorption lines are produced very much in the fashion in which the D lines of sodium are seen as dark lines against a bright, continuous background in the sodium reversal experiment in elementary physics courses.



The antenna and fork of the Agassiz Station radio telescope. En route from Cohasset to Harvard, Mass. (4 Jan. 1953).

galaxies outside our own, with the exception of the two Magellanic Clouds. The Large and the Small Star Clouds of Magellan are too far south for Northern Hemisphere observers, but they are in excellent position for study from Sydney, Australia, where Kerr, Hindman, and B. J. Robinson have investigated them with their 21-cm equipment. Before the Australian astronomers began their work, optical astronomers were pretty well agreed that the Large Magellanic Cloud is rich in hydrogen gas, but most of us supposed that there would be relatively little hydrogen in the Small Cloud. Kerr and his associates have demonstrated conclusively that atomic neutral hydrogen, as revealed by the 21-cm line, is abundant in both the Large and Small Clouds. The two Clouds are observed to be imbedded in very large and bright massive clouds of neutral atomic hydrogen, with the total hydrogen content of the Small Cloud being only relatively little less than that of the Large Cloud.

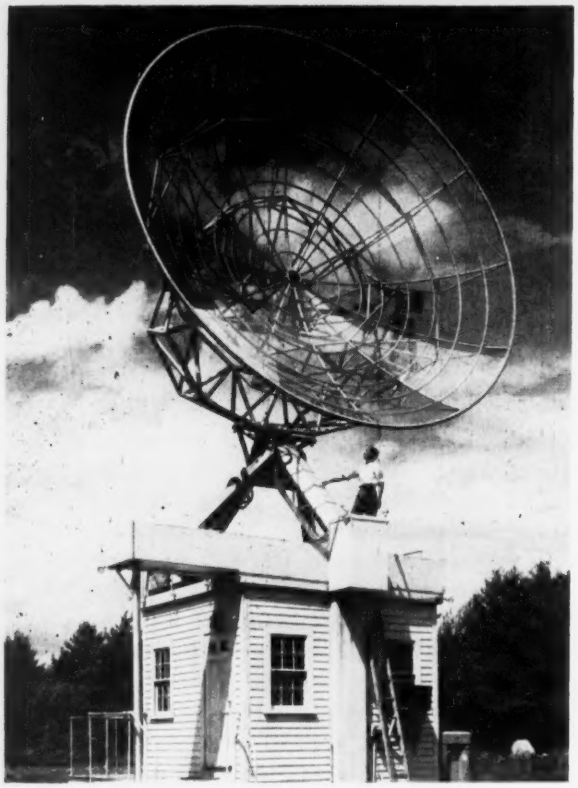
I have purposely listed in considerable detail in the foregoing paragraphs the most striking discoveries obtained to date from the study of the 21-cm spectrum line alone. The accomplishments in their considerable variety demonstrate the versatility of the new approach to the study of the interstellar medium. In considering these accomplishments we should keep in mind that the original discovery by Ewen and Purcell was made only 4 years ago. Already it has become virtually impossible for the Milky Way astronomer to think of his field of research without considering studies of the 21-cm radiation. The potentialities for future research are tremendous. For studies of our own Milky Way system, we stand to gain a great deal from the use of larger antennas to provide us with greater resolution in angle and from further electronic developments.

The future detection and study of 21-cm radiation from the nearby galaxies and from the remote clusters of galaxies promises to yield some very useful basic information about these galaxies and the motions of the gases within them. The detection of intergalactic neutral hydrogen, which now presents a very difficult problem, becomes something to be dealt with in the future. We should remember at this point that, up to the present time, we have been dealing with only one single spectrum line, that near 21 cm. It is not impossible that other lines do exist, and the search for two of the most likely ones, the deuterium line at the frequency of 327 Mcy/sec and the components of an OH band at 1667 Mcy/sec, are on the high priority list.

Future of Radio Astronomy in the United States

Radio telescopes are now in operation in the United States at the Naval Research Laboratory and at the Department of Terrestrial Magnetism of the Carnegie Institution in Washington, D.C., at the Agassiz Station of Harvard Observatory, at Cornell University, and at Ohio State University. The National Bureau of Standards has a program on the way, and the California Institute of Technology is entering the field, but this about completes the picture. At present only three universities have graduate students in radio astronomy, and the total number of graduate courses in the field offered during the past year has not been more than five. Radio astronomy is a field in which success can be achieved only if astronomers, physicists, and electronic engineers work in continued close collaboration, and there are unfortunately very few institutions where collaboration of this sort is now in effect. This is certainly a meager showing for the United States in a field that holds as much promise as does the new radio astronomy.

Fortunately, the scientists of the United States who should concern themselves with radio astronomy are very much aware of the need for increased activity in this young field. In 1953 there was a gratifying response to the *Symposium on Radio Astronomy* organized by Sections D and B of the AAAS. Early in January 1954 the National Science Foundation called together in Washington a 3-day meeting of radio astronomers, established and potential, from the United States and invited some of the leaders from abroad. Much enthusiasm was expressed at the Washington symposium for increased United States activity in radio astronomy, and the NSF has since established a special panel on radio astronomy. Under the able chairmanship of Merle A. Tuve, the panel not only concerns itself with the judging of applications for financial support for the immediate future but also has as its primary assignment the task of promoting the development of an effective effort in the field in the United States.



The Agassiz Station radio telescope.

There is no denying that radio astronomy is an expensive science. If we wish to participate in research in the meter-wavelength range, we must build equipment that has greater resolution in angle and permits settings with higher precision than is available today. A very large steerable paraboloid, or a fixed one, or instruments of very novel design, may be the answer to some problems; but, since energy is plentiful at meter wavelengths, other problems can be solved more effectively through the use of interferometer or pencil-beam techniques. In the range of centimeter and decimeter wavelengths, we are looking mostly for instruments that will give increased angular resolution and at the same time will gather more of the very weak radiations that reach us at these wavelengths. For the time being, large steerable paraboloid antennas seem to be the preferred instruments for the shorter wavelengths, but we should be aware of the possibility that improved electronic instruments may make it advisable to consider interferometric and pencil-beam techniques a year or so from now, not only for the long but also for the short waves. The end of major new developments in electronics is still not in sight. A considerable portion of the funds available for the construction of a large radio observatory should, therefore, be set aside for research and development in electronic instrumentation.

The financial support for our existing American radio astronomy enterprises has come from a variety of sources. The principal contributors to the project in radio astronomy at Agassiz Station have been the National Science Foundation and an anonymous benefactor interested in the project at the station. Without the support from these two sources, we could not have begun the project of building the present 24-ft Agassiz Station radio telescope and its electronic apparatus, and we would not now be building a new 60-ft reflector with much improved electronic equipment. We are depending for the remainder of our funds for basic operation on assistance received from Harvard University, and, at a critical stage in the construction of our electronic apparatus, the Research Corporation came to our rescue with a special grant.

At Ohio State University, the remarkable developments in antenna design by Kraus have been supported by the university and in part by the NSF. The Carnegie Institution of Washington itself is financing the three projects under way at the Department of Terrestrial Magnetism. Navy and Air Force funds have played an important part in some of the remaining projects—especially those related to solar research. All of us in the field of radio astronomy have reason to be grateful for the splendid ways in which the U.S. Navy has supported Hagen's project at the Naval Research Laboratory in Washington.

Radio astronomy holds a special position as a cross-field science—part astronomy, part physics, and part electronic engineering—for which technical advances in electronics and in the design of antennas are of critical importance. For success in the field, the radio astronomer requires the strongest possible support from industry in the design and construction of his sensitive apparatus. In return for the help that has been freely given by some of the leading electronic industrial concerns, especially by manufacturing companies of radar antennas, the radio astronomer performs as a part of his researches some very exhaustive tests of the equipment and makes recommendations for improvements that may have value for applied and industrial research in the field.

Cooperation as suggested in the foregoing paragraphs has proved to be all important in the development of radio astronomy at Harvard University, where Ewen and I are receiving the strongest possible support, not only from our colleagues at Harvard and the Massachusetts Institute of Technology, but also from New England

industry. I mention this simply because similar opportunities for cooperation exist in at least eight or ten other academic communities in the United States, and we must take advantage of this happy circumstance in the development of radio astronomy enterprises elsewhere in the country.

Before too many years elapse, the United States should have one or more new major establishments with first-rate equipment in the field of radio astronomy. Associated Universities, Incorporated, the organization that has, with such signal success, initiated and operated the Brookhaven National Laboratory, is inquiring into the establishment of a large cooperative radio observatory somewhere in the eastern United States. All of us interested in the development of radio astronomy in the United States should give our full support to this project.

After far too long a period of relatively little activity, radio astronomy in the United States is finally getting really under way. As a result of our first efforts, we have obtained scientific results that are recognized to be of value. Experienced personnel is beginning to accumulate, and graduate training on a modest scale is under way. We are developing our instrumentation, and we are beginning to think in terms of equipment that should make possible really worth-while research advances. I am sure that, if scientists and administrators continue to give it increasing support in the years to come, we shall be in a position to make vital contributions to the new science of radio astronomy.

Naval Research Laboratory's 21-cm Antenna

The cover photograph this month shows the 21-cm antenna that is installed on the 50-ft radio mirror at the Naval Research Laboratory in Washington, D.C. (see page 334). With this installation, NRL radio astronomers, in May 1954, discovered the absorption of 21-cm radiation by hydrogen clouds in the Milky Way. Use of the absorption technique developed by NRL scientists in connection with this investigaton will enable astronomers to determine the distances to so-called "radio stars"—discrete radio sources in the sky.

What Is Ecology?

LEE R. DICE

The author is professor of zoology and director of the Institute of Human Biology at the University of Michigan. Previously, he had taught at Kansas State Agricultural College, the University of Montana, and the University of Illinois. Dr. Dice received his Ph.D. in zoology from the University of California. He is the author of numerous research papers and of three books: Biotic Provinces of North America, Natural Communities, *and, with P. M. Blossom, of* Studies of Mammalian Ecology in Southwestern North America.

THE science of ecology has now approached, if it has not already reached, an early state of maturity. Rarely heard nowadays is the irritating statement that ecology is not a science, but only a point of view. Nevertheless, it is desirable from time to time to take stock of our science. I shall, therefore, review (*1*) briefly the scope, methods, and major concepts of ecology. I shall also survey quickly some of the applications of ecologic knowledge. This review is presented in all humility, knowing that individual ecologists will disagree, sometimes violently, with my definitions, conclusions, and points of emphasis.

The definition that ecology is the science that deals with the relationships between organisms and their physical and biotic environments is accepted by practically everyone. Certain ecologists, however, construe this definition in a very broad sense. They include in ecology almost all of biology, omitting only a few special subjects, such as cytology or certain phases of genetics. Others restrict the definition of ecology much more narrowly. There is in fact little agreement among ecologists concerning the precise scope of the science.

The history of ecology includes attempts by various authors to define the science and to establish its subdivisions. For a brief review of this history, reference is made to a recent paper by Van der Klaauw (*2*), who clearly shows the lack of agreement among ecologists concerning the limits of ecology and also concerning the limits of its subdivisions.

A committee to define the science of ecology and to specify its scope and place among the sciences was appointed in the early days of the Ecological Society of America. This committee acted with commendable diligence and asked the advice of certain members who were assumed to have opinions on the subject. After pondering the answers that it had received, the committee reported to the next annual meeting of the society on its progress and asked to be continued for another year. In its second year the committee proceeded to draw up a set of definitions with illustrative examples. It submitted these to many members of the society for further comments. The resulting accumulation of opinions seems to have produced a severe case of indigestion. At the following annual meeting the committee reported itself unable to reach any agreement and asked to be dismissed. And to this day no one knows just what the scope of ecology is.

Instead of being distressed at this failure to agree upon precise boundaries for ecology, I consider it a healthy situation. It is impracticable to attempt to establish limits for any science. In this conclusion I am in full agreement with Walter P. Taylor (*3*). A strait jacket is no more suitable for a science than it is for a healthy individual.

All science is interrelated. Ecology has intimate relationships with many other branches of biology, with certain of the physical sciences, and with numerous phases of social science. Any attempt to draw boundaries between these closely related sciences will do more harm than good. Every ecologist, like every other true scientist, must be free to pursue his investigations wherever they may lead, without hindrance from artificial boundaries among the sciences.

What then are the features of ecology that distinguish it from other sciences? Most sciences have developed special methods of study. Ecology is no exception. An example of a special ecologic method, applied in many field studies, is the use of sample quadrats for the analysis of vegetation and other features of communities. Numerous other special techniques are used by both field and laboratory ecologists.

Most sciences have special vocabularies. Special scientific terms are needed for clarity and ease of communication. Communication is made more difficult, however, instead of being aided, when many new and poorly understood terms are encountered in scientific reports. In the early days of

ecology certain persons introduced an overabundance of new terms. This caused much criticism. Relatively few new terms are being currently introduced by ecologists. Over the years, however, ecology has accumulated a rich special vocabulary. Examples of useful ecologic terms are *community, ecosystem, food chain,* and *succession.*

The most important part of any science, however, is its concepts, as has been pointed out by Daniel Kashkarov (*4*), the eminent Soviet ecologist. The concepts of ecology are those principles, natural laws, theories, and hypotheses that attempt to explain the relationship of organisms to their environment.

What fruitful concepts has ecology developed? No two ecologists would make exactly the same answer to this question. The concepts that I shall describe must consequently be understood to be my own selection only. Further, I shall make no attempt to list all the concepts that have been developed in ecology, or even all the more important ones. I shall discuss only a few of those that seem to me to have the greatest significance.

Levels of organization. One of the major concepts of biology is that living material is organized at a number of levels of complexity. Particularly important levels of organization, from the point of view of the ecologist, are represented, first, by the individual organism; second, the species; third, the social group composed of members of a single species; and fourth, the community composed of several to many species of plants and animals. Each of these units of organization has its own special relationships to its environment.

The individual organism is itself composed of organs that function in organ systems. The organs in their turn are composed of tissues and cells. Each cell contains a nucleus and cytoplasm, which are themselves made up of still smaller parts. The main function of all this complex internal organization is to enable the individual organism to adjust effectively to the conditions of its habitat, to obtain energy in order to continue to live, and to reproduce its kind. By means of its organization the individual reacts and operates as a unit to secure food, perchance to escape from enemies, to reproduce, and above all to maintain constantly a tolerable degree of adjustment to the vicissitudes of the changing environment.

The species forms a level of biologic organization above that of the individual. From the ecologic point of view the species is of interest because all its members have similar, although not necessarily identical, relationships to their individual environments. The individual organisms, of which each species is composed, are potentially able (with certain exceptions) to produce offspring that resemble their parents in their characters and in their reactions to the habitat.

A social group may be considered to be any aggregation of individuals of the same species that are cooperating for their mutual benefit. Many kinds of animals, including man, are successful mostly because of their social habits. The outstanding success of man as a species is in considerable part due to the fact that he lives in social groups. The social level of organization is, consequently, from the human viewpoint a very important one.

All those plants and animals that live together in the same situation and are ecologically interrelated together constitute a community. Although some communities are composed of only a few individual organisms and a still fewer number of species, most communities are made up of thousands or even millions of individuals and of hundreds of species. In the usual community, green plants, herbivores, carnivores, parasites, saprophytes, commensals, and other types of organisms cooperate to form a more or less self-contained unit. The ecologic community consequently represents the most complex level of organization of living matter that has evolved on our planet.

Energy relationships. The second concept of importance in ecology to be considered here involves energy relationships. The maintenance of life requires the constant expenditure of energy. Practically all the energy that is utilized by living organisms is derived directly or indirectly from the sun in the form of light and heat. Green plants utilize solar energy to transform fairly simple chemicals into more complex compounds. The carbohydrates, fats, and proteins elaborated by the green plants can be used as food by herbivorous animals. Herbivores in their turn are eaten by carnivores or their substance absorbed by parasites. The resulting food chains within an ecologic community are usually very complexly interconnected. The energy relationships within a community involve also the use of dead organic material by saprophytes and the transformation of this material into compounds that serve to nourish green plants. The energy relationships among the several member species of a community are consequently often highly involved.

Ecosystems. One of the most fruitful concepts of ecology is that each community, together with its physical habitat, forms an interacting system, the ecosystem (*5*). In part, the habitat controls the species of organisms that can exist in each

particular situation and thus it plays a large role in determining the kind of community that can develop there. The community, however, interacts with and modifies the habitat in such a way that this often becomes more suited to support the community. The habitat thus becomes adjusted to the community at the same time that the community becomes adjusted to the habitat.

Individual organisms and societies also form interacting systems with their habitats, as has been pointed out to me by Francis C. Evans. Unfortunately, no good terms seem to have been invented so far to differentiate between individual and societal ecosystems and the ecosystems that are based on communities.

Ecologic balance. The individual organism is able to continue to exist and to adjust itself to the changing conditions of its habitat because it possesses effective internal regulatory mechanisms. The ecologic balance between the individual and its habitat has been called *homeostasis* by Cannon (*6*). A similar condition of ecologic balance is maintained between every community and its habitat. Here it is sometimes spoken of as the *balance of nature.* Ecologic balance, whether of individuals or communities, is never a static condition to which the system has a tendency to return, but is always a dynamic balance (*7*). The ability of living material at every level of organization to adjust to the frequent fluctuations in the environment and to maintain a generally tolerable stability is probably the most important concept of ecology, as it is indeed of all biology.

Reproduction. Not all individual organisms succeed in maintaining a tolerable adjustment to their habitats. A violent oscillation of the environment, for example, may cause heavy mortality among numerous species. Predation, parasitism, and competition also may result in the loss of individuals. To compensate for this mortality, every kind of organism must have effective means of reproduction. Young organisms are subject to particularly heavy mortality. Many species, therefore, have developed special adaptations for reproduction and for survival over the critical juvenile age.

Communities, as well as individual organisms, are subject to mortality, owing to environmental pressure or competition from other communities. New communities may arise through the expansion of existing stands and the later loss of connections between certain of their parts. This type of reproduction is similar to the budding exhibited by many species of plants and by a few animals. New communities also may arise through the formation of new aggregations composed of the proper member species. Inasmuch as the several member species of one type of community often are members also of other communities, reproduction of communities may occur without direct descent from any single parent community.

Competition. Every species, by reason of its reproductive capacity, produces in each generation more offspring than can possibly survive. The surplus of individuals thus produced causes competition among the members of the same and of associated species. Heavy mortality often results from this competition among individuals.

When competition occurs between two communities that differ in type, one community is likely to displace the other. Such a displacement results in ecologic succession. Although succession is an important concept, it is by no means the only or even the most important concept of ecology, in spite of such an assumption by certain social scientists.

Variability. The individuals who together make up any given population vary among themselves in heredity and also in the ways they have been affected during their past lives by their individual environments. Because of their individual variability, organisms of the same species vary more or less in their relationships with their habitats. Habitats are also far from uniform. The relationships between organisms and their habitats is consequently subject to a high degree of irregularity. As a result of such irregularities, a community seldom has exactly the same characters in any two spots.

Ecologic patterns. In spite of the variability that is so evident in ecologic distributions, certain combinations of species recur again and again, thus producing ecologic patterns. The frequent recurrence of essentially similar aggregations of plants and animals indicates that certain ecologic combinations are more stable than random aggregations of species. It is these recurrent patterns of combinations of species that constitute ecologic communities. Recurrent ecologic patterns are evident in ecosystems of all sizes—from those that extend over vast geographic regions down to the most minute situations in which life can exist. Ecosystems of many ranks and sizes can consequently be recognized.

Individual adaptability. Organisms vary considerably in ability to adjust to their individual environments, depending in part upon their complexity of organization. Every organism, however, no matter how simple in type, does have some power of adjusting to its habitat. The adjustment to the factors of the physical environment is called *acclimation.* No special term is used to designate adjustment to the biotic features of the habitat,

although it is evident that such an adjustment often is essential for the survival of the individual.

In adjusting to its environment each individual organism makes use of physiologic processes that often are very complicated. Animals may in addition possess complex nervous mechanisms which control muscles that move certain appendages or the entire individual. Mobile animals, consequently, are able to escape from an unfavorable situation and to seek out a habitat that is suitable for their survival. The animals that have highly developed nervous systems may be especially sensitive to certain kinds of external stimuli. The higher types of animals, furthermore, are able to adjust their behavior through the use of intelligence and, more rarely, of reason.

The subdivision of ecology that deals with the relationships of the individual to its environment is physiologic ecology or individual ecology, sometimes called *autecology*. Certain phases of the subject also involve animal behavior. The distinction here from physiology is that, as usually treated, physiology is concerned mostly with the internal mechanisms of response and often gives slight attention to the external conditions that stimulate the organism to action. Animal behavior similarly differs from comparative psychology in being concerned primarily with the results secured by the animal through its response to the factors of the environment rather than with the mechanisms of the nervous response itself.

Evolution. The adjustments that individual organisms make to their environments are not inherited. The capacity of adjusting in a particular way, however, often is characteristic for the species concerned and so also are the limits of amplitude of the response. The characteristic mode of response of the members of each species, consequently, is in considerable part based on heredity.

A change in its heredity that improves the adjustment of a species to its environment is called *evolution*. The improvement that occurs may be either a change in structural characters or in physiologic ability to adjust to the environment. Through evolutionary changes in heredity, there have been developed all the diverse adaptations of the myriads of species of plants and animals that now live on the earth as well as of all those species that have lived in past ages.

Natural selection is one of the most effective agencies for producing adaptive evolution. A well-adapted individual has, on the average, a better chance to survive and to produce offspring than an individual that is poorly adapted to its environment. Natural selection is, consequently, a very powerful ecologic force.

Social cooperation. Through evolutionary changes in their psychology, many species of animals have acquired the habit of cooperating with their fellows. By living in social groups, for example, man is able to live and sometimes to thrive in environments that otherwise would be too rigorous for him. The point here emphasized is that social behavior produces special relationships between organisms and their physical and biotic environments and, consequently, involves at least in part the ecology of the situation.

This brief list of the more important concepts of ecology calls attention to the fact that the science of ecology occupies a strategic central position among the biological sciences. Many of the more important concepts of biology deal with ecological relationships. Adaptive characters, adjustment of the individual organism to changes in its environment, regulatory mechanisms in the individual and in the community, energy transfer in the community, and the evolution of species by the action of natural selection, are examples of important ecologic concepts.

No claim is made, of course, that these or any other concepts are exclusively the property of ecology as opposed to other sciences. Certain of these concepts are in fact important for several different biological sciences. This again demonstrates that the boundaries among the sciences cannot be sharply drawn.

Let us now turn to a consideration of the application of ecologic principles to human affairs. This survey must of necessity be extremely brief.

Ecologic principles in human affairs. Many human activities are concerned with the relationships between organisms and their environments. In primitive human communities, for example, success in hunting and fishing must often have depended upon a knowledge of the habits of the food species and of the habitats where these species could be found. In food gathering, also, it is necessary to know which plants and animals are edible and where and in what seasons these foods are available. Primitive man consequently had to be an ecologist, at least to some degree. Pastoral and agricultural man likewise depended upon ecologic knowledge for raising his domestic animals and for growing his crops.

Increase in ecologic knowledge has made enormous improvements possible over the empirical rules used by primitive man. Ecologic methods and principles are used extensively in modern wildlife management, forestry, range management, and agriculture. Modern man, no less than primitive man, is dependent for his continued existence on the productivity of the lands and waters of the

earth. Practical ecology consequently forms the basis for every human community no matter what its stage of culture.

A human community actually is only a special type of community in which man happens to be a conspicuous species. Man is able to control his habitat to a far greater degree than any other animal. Through social and economic cooperation he has evolved extremely complex types of communities. Much of man's success also is due to his ability to transfer elements of culture from person to person and from generation to generation. Nevertheless, man is completely dependent upon his plant and animal associates for food and for many other items essential for his very existence. Each man must be a member of some ecologic community in order to live. The basic similarities between human communities and unmodified natural communities have been pointed out by Adams (*8*), Sears (*9*), and numerous other ecologists.

Unfortunately, very few quantitative studies have been made of human communities from the ecologic viewpoint. Most past studies have dealt only with certain limited aspects of the community, such as the fish, game, forage for domestic animals, timber, mineral resources, soils, or the human population alone. No comprehensive study has yet been made of any human community that presents adequate information about the resources, the important associated species of plants and animals, the human population, and the regulatory mechanisms that actually operate to keep the community in balance with its resources.

The problems of parasitology, microbiology, hygiene, and public health are concerned mostly with ecologic relations. Certain aspects of medicine also have an ecologic basis. The great progress made in medicine and public health in recent years has considerably decreased the human mortality rate in most regions. As a consequence, the populations of certain countries have become overly dense in relation to their resources. The adjustment of population density to carrying capacity and the improvement in level of living is an ecologic problem that currently is receiving serious attention in many parts of the world.

Geography is to a considerable degree concerned with the ecologic relationships between organisms and the physiography and climate of the areas where they live. Most geographers give the ecologic relationships of man a large share of attention.

Anthropology also is concerned with the ecologic relationships of man. The material features of each human culture are greatly affected by the local climate and physiography, the more abundant local plants, animals, and diseases, and the productivity by the habitat of human foods and other useful materials. Even religious beliefs and other nonmaterial features of culture may be affected to some degree by the characters of the ecosystem.

Human history is in part a story of the adjustment of peoples to the conditions of their local habitats and the development and utilization of natural resources. A home area that is richly productive of food and other valuable materials, for example, has frequently enabled a tribe or nation to expand its population and to enrich its culture —with the result that its relationships to its neighbors have been altered. The history of every part of the world has been affected by the ecologic relationships of the inhabitants with their habitats and resources.

Certain aspects of sociology also are concerned with ecologic relationships. Several recent sociological books (*10*) have in fact carried the term *human ecology* in their titles. One book that deals in part with economics has also used the term *human ecology* in its title (*11*).

It is evident, therefore, that many of the social sciences, as well as the biological sciences, are making use of ecologic concepts. It is further evident that interest is steadily increasing in ecologic relationships, especially in those that concern man.

The application of the principles of ecology has been helpful in the solution of many problems that are of importance to man. In our present state of knowledge, however, many problems are still too difficult for us. Sound ecologists do not pretend that our methods and present knowledge can now or ever will be able to solve all human problems. The recent attempt, for example, to correlate the type of paintings produced by the artists of a given age with the climatic conditions at the time seems to me to go beyond our abilities. I seriously doubt that any ecologist can by inspection of a particular painting of a lady at her bath deduce that the artist was living in a dry, warm stage of climate! Yet a recent article (*12*) in the *Journal of Human Ecology* seems to imply that such a deduction is possible.

In this brief review I have attempted to show that the science of ecology has no natural boundaries. Ecologic principles and methods are usefully employed in many of the biologic sciences and in a number of the social sciences. It seems almost certain that as time goes on ecologic concepts will be applied to many additional aspects of human affairs. It is the responsibility of ecologists to make sure that their general concepts are soundly established. Serious effort should also be exerted to ex-

press ecologic principles in terms that are clearly understandable and so to facilitate their application to human affairs.

I earnestly urge all ecologists, especially the younger ones, to give serious consideration to the basic concepts of ecology. The gathering of ecologic facts is, of course, useful. The most valuable results, however, will always be obtained when the facts are gathered in such a way as to support, modify, or contradict a current hypothesis or, perchance, to formulate a new explanation. The basic concepts of ecology, like those of every other science, should be constantly scrutinized, added to, and revised. The vital part of ecology consists of its natural laws, theories, and hypotheses.

Much still remains to be learned about the relationships between organisms and their environments. Although it is well known, for example, that individuals and communities maintain a working adjustment with the changing conditions of their habitats, relatively little is known of the precise means by which in any given situation this adjustment is achieved. The application of quantitative methods to the solution of ecologic problems is another phase of study that can be expected to develop rapidly in the near future.

In my youth I, like many other youngsters, worried for fear that all the important discoveries of science would be made before I could grow up. Actually, the more we learn, the more complex nature is found to be. This is especially true of ecologic relationships. We shall probably never discover all the secrets of living matter. I confidently predict, nevertheless, that ecologists will as time goes on make increasingly significant contributions to the understanding of the world of life.

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Science, as its name implies, is primarily knowledge; by convention it is knowledge of a certain kind, the kind, namely, which seeks general laws connecting a number of particular facts. Gradually, however, the aspect of science as knowledge is being thrust into the background by the aspect of science as the power of manipulating nature. It is because science gives us the power of manipulating nature that it has more social importance than art. Science as the pursuit of truth is the equal, but not the superior, of art. Science as a technique, though it may have little intrinsic value, has a practical importance to which art cannot aspire.—Bertrand Russell, *The Scientific Outlook* (1931).

Cultivating Our Science Talent—Key to Long-Term Security

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THE day-by-day and week-by-week ebb and flow of world tension brings up many short-range problems: the best course of action in the Formosan Straits; stemming Communist infiltration and subversion in southeast Asia; bringing West Germany into the NATO community; and many others. We are all properly concerned with these things because any one of them might have serious consequences for us. Under the pressure of these day-by-day affairs, however, we must not lose sight of the longer range problems. I should like to focus attention on one of these. My thesis is that, like it or not, we are in a race for technologic supremacy with the Communist world and that our long-term security may well depend on the outcome of this race.

My first theorem is that, within the memory of even the youngest of us, science and technology have revolutionized the art of warfare. I will cite three or four pieces of evidence to show that this is true.

Although it was apparent before World War II began that airplanes would play a vastly more important role in any future war than ever before, the events of the early months of World War II left no doubt that air supremacy would be decisive. Air supremacy, however, meant much more than just airplanes. In the Battle of Britain, for example, the British attributed the success of their relatively weak interceptor force in stopping the German night bombers to the fact that their recently developed and installed radar network gave them vision in the darkness and, thus, early enough warning to enable their interceptors to track down and destroy the invading bombers. Thus, military electronics joined aeronautics as a decisive factor in the Battle of Britain.

Another instance of the decisive role of electronics was in October 1944 when the Japanese Navy decided to make an all-out attempt to envelop and destroy the U.S. Naval forces in Leyte Gulf. The southernmost of the three Japanese task forces attempted to pass through Suragao Strait under cover of darkness. They were met by U.S. Naval forces which were equipped with precision fire-control radar. The Japanese task force was almost completely annihilated by our radar-directed gunfire in a night engagement that left the Japanese gunners blindfolded. The ability of radar to see and measure position at night was the decisive factor.

It was toward the end of the war that nucleonics entered as the third decisive element of the new technology. United States air power in the far Pacific, including the electronic equipment required to make it effective, had already broken the back of enemy resistance. It was, however, the atomic bombs over Hiroshima and Nagasaki that clinched the victory.

The war ended with general recognition by the experts that the new technology, with nucleonics, aeronautics, and electronics in stellar roles, would thenceforth be dominant in any all-out war.

Events in the following decade have confirmed and strengthened this conviction. Both sides have made great efforts to capitalize on the new technology and to extend and perfect it to maximum military advantage. Great strides have been made. World War II planes would be completely outclassed by the jet planes of today which fly at altitudes and speeds that were only dreamed of a decade ago. Electronics has been pushed ahead so far, and its performance so greatly extended that World War II designs now seem crude and in-

effectively by comparison. And, finally, the nuclear sciences have been advanced to the point where explosive forces have to be measured in millions of tons of TNT equivalent rather than in the tons of World War II blockbusters and the thousands of tons of the Hiroshima and Nagasaki bombs.

As we look back on the period immediately following World War II, we see that we were too complacent in assessing our technical position relative to the Communist world. We knew we had left a lot of equipment of advanced design with the Communists and that the Germans had been the unwilling donors of a lot more. We knew also that a lot of the German scientists who had worked on the development of new weapons had been persuaded by unspecified methods to move behind the Iron Curtain and continue their work for the Communists. Still we were quite smug about it all. Even when it was learned that some very important secrets had been passed covertly behind the Iron Curtain, we still could not believe that the Soviets were serious technical competitors.

Many things have since conspired to force us to change our estimate. It will suffice to mention one in each of the three major fields. The Soviet atomic test in the fall of 1949 showed that the Communists had broken our monopoly in this field; their thermonuclear test in August 1953 left no doubt that rapid progress in nucleonics was being made behind the Iron Curtain. The large numbers of jet fighters that the Communists used in Korea, together with the jet bombers of very advanced design which they flashed in their May Day air show last year in Moscow, left no doubt of their progress in aeronautics.

The evidence in electronics, although a bit more obscure, is equally convincing. Perhaps the best single example was afforded by the U.S.S.R. light cruiser "Sverdlov" when it appeared at the British Coronation ceremonies a year or so ago. Most of the electronic equipment on one of our cruisers of similar class is out of sight, but the antennas have to be out where they can see and, therefore, be seen. Moreover, to the expert, the antenna design tells a lot about the rest of the equipment. Suffice it to say that the "Sverdlov" showed up with about the same number and kind of antennas that one would find on the superstructure of one of our own cruisers of similar class. These could have been fakes and the guns could have been made of wood, but the time is past when we can derive any comfort from this kind of reasoning. It is clear now that in nucleonics, aeronautics, and electronics—in fact, in military technology broadly—we are confronted in this race by a strong competitor. This is my second theorem.

My third theorem deals with the mechanism by which our competitor has made his progress. Technologic position is a complicated thing, involving industry, skilled manpower, raw materials, and other factors. We know that at least in the first two of these, the Communists were far behind us at the end of World War II. But Communism has always worshipped materialism, and the Soviets have always been willing to sacrifice everything else to advance their ambitions for world domination. Specifically, they have been willing to apply much more of their resources to their heavy industries, which in large measure were war-supporting industries, leaving much less to consumer goods than we, in this country, would be willing to accept as a steady diet. In fact, Malenkov, who placed more emphasis on consumer goods, was allowed to listen to a confession of his incompetence and to step aside.

With regard to raw materials, the Communists now dominate a sizable part of the world. On the basis of an austere military-oriented economy, raw materials, with the possible exception of oil, should not pose too serious a problem for them.

It is perhaps in the scientific and technical manpower area that the Soviets have shown the greatest resourcefulness. Recognizing that material progress is paced by science and technology, they have multiplied by a factor of 10 the number of their institutes of higher learning in these fields. Moreover, where less than a third of the students in our universities specialize in engineering and the physical sciences, more than two-thirds of their comparable students specialize in these fields.

Numerically, their results are impressive. They are now graduating well-trained scientists and engineers at more than twice the rate we are in this country. If present trends continue, it will be only a matter of a few years before their scientific and technical manpower pool passes the size of our own.

This, of course, is not conclusive—the results depend, too, on how well their professional people are trained and how effectively they are used. Parenthetically, I must make it clear that I believe that the freedoms and incentives of our system give us a big advantage in this regard, and that their pool would have to be considerably larger before it could equal the effectiveness of our own. Nevertheless, these statistics must give us pause. We certainly can no longer take our superiority in military technology for granted. We must take stock of our own manpower resources and make sure we are developing and using them to our best advantage.

Perhaps at this point we should digress a few moments to consider the principal claimants for

scientific and engineering manpower in our modern society and under present conditions of world tension.

Probably the most important claimant for a share of our scientific and technical personnel is our educational system and the basic research activities carried on in our universities and institutes of higher learning. This is the seed corn that must be saved to insure the next crop of scientists and also the next crop of scientific discoveries. Nothing could be more shortsighted than to consume our seed corn in our current applied programs, unless, of course, the danger becomes so acute that all else must be sacrificed.

Next, industry is a claimant for a large share of our skilled manpower. Our long-term economic health and military strength depend heavily upon the forward progress of industry and upon its opening up for our expanding labor forces whole new fields of industrial activity.

There, too, is the requirement for a strong military research and development program to advance military technology and to improve our weapons and our systems of using them. Our present program utilizes directly or indirectly about half of the scientists and engineers available in the country for this kind of work. We could be hopelessly outclassed if we dropped this part of our program.

Finally, the military departments require a certain quota of scientists and engineers to support the very highly technical operations that are being developed and tested for use by our armed forces. Some of this quota of professionally trained people will be in uniform; most will be working in military laboratories, test stations, and the like.

Altogether, as the pages of "Engineers Wanted" advertisements in our daily newspapers indicate, there are many more claimants than there are scientists and engineers. Moreover, studies indicate that this imbalance may be expected to get worse, rather than better, in the years that lie immediately ahead.

There are a number of things happening today that have an important bearing on this problem. The President has sent to the Congress proposed legislation to modify and extend the Selective Service Act and to revamp the National Reserve Plan in order to align these with present-day realities. One of the features of the new plan will be to sharpen our practices in the utilization of scientific and engineering manpower—to see that professional skills are used to best advantage, both inside and outside of the armed services. The objective is not to relieve scientists and engineers of the obligation to serve. They are as conscious of this obligation as any others—perhaps even more so—because their whole training is directed toward service. Nor is the objective to find safer places for them to serve. There are not going to be any safe places in the next world conflict, and particularly not in the laboratories and factories where important research and production are being carried on. The point here is that, in planning and organizing for the utilization of skilled manpower, we must put the national interest first. This means that, in spreading equitably the obligation to serve, we must use the professional skills where they are most essential to our national security and welfare. This principle applies to doctors, and it applies to nuclear physicists, aeronautical scientists, and electronics engineers.

My third theorem is, then, that scientific and technical manpower is our most precious commodity, our real critical resource, that our competitor is being very smart in fostering and conserving his stock of this precious commodity, and that we must sharpen our own practices all along this line.

This leads me to my fourth and last theorem, which is that our system of supply of scientific and technical manpower needs a critical reexamination. This is a big subject that touches on almost all phases of our social and educational system. It is, in the first instance, a personal problem involving the interests and ambitions of our individual young people. It is, next, a local problem involving the will and ability of the community to provide educational facilities. Beyond this, it is a state problem involving state aid to the local schools and state support of institutions of higher learning. It gets to be a federal problem, as the President pointed out in his message to the Congress in February, when circumstances make it impossible for state and local agencies to handle the problem adequately.

Since we cannot afford to let such situations go by default, the President's message proposes new legislation that will lend federal assistance, with a minimum of federal interference, in those critical cases most in need of aid. The proposal would make some $3 billion available for such federal assistance in the years immediately ahead. This, of course, is only one of the ways in which the Federal Government is promoting education and research. Others, for example, are research and development contracts, research grants, and special scholarships, which all together support more than half of the research and development in the country today. The new proposal would, however, help to plug an important gap in our present skilled manpower supply system. In our secondary

schools today there is a serious and growing shortage of teachers in mathematics and the physical sciences. The local communities, with the help of local industries, can do a lot to make up for this shortage.

My fourth theorem is that it is a matter of national necessity that we strengthen our system of supply for professional-grade scientists and engineers.

These four theorems bring me back to my original thesis—that the problem of enabling and encouraging young people to seek professional careers in science and engineering is one of the most important long-range problems facing us today, and that our success in this respect will have direct bearing on the outcome of the technologic race between our free society and Communist dictatorship.

I realize that, in placing emphasis as I have on technology, I have been guilty of a kind of materialism, an implication that material well-being is the highest aspiration of mankind. I do not believe this. We are, however, in a cold war with a ruthless communism that makes materialism its highest aim, and as long as our security is theatened we have to give first priority to the material means of defending and preserving our way of life. We must also recognize, however, that our success in this competition in the long pull depends on preserving and strengthening our moral and spiritual fiber and on preserving and continually improving our social system so that we may demonstrate to the rest of the world that we do in fact have the best system, and that the individual dignity and freedom which we cherish is in fact worth fighting for, and, if necessary, worth dying for.

I can recall only part of a talk I once heard at a sales meeting. I think the speaker had a point. He said, "You are talking to a parade. Three million Americans never saw an elephant, that is why the circus will come back next year." "Same old stuff," you say—same stunts, same clowns, same animals, same ballyhoo you saw when you were a kid. Yes, largely true, of course, but since that same old elephant stalked through the streets a year ago, three million new Amricans will have arrived in this country—three million more people who have never seen an elephant. That's why the same old elephant walks serenely confident that among every bored group of people who say "That's just an elephant" some eager young voice will shout "Oh! That's an elephant." You are not talking to a grandstand, you are talking to a parade. I think this applies to teaching. The simple experiment that first aroused our interest in physics will have the same effect upon each new group that comes to us for instruction.—R. C. Grubbs. "Demonstrations in high school physics," *School Science and Mathematics* **11**, 199 (1948).

An Insect Pompeii

REGINALD D. MANWELL

The author, who has served as professor of zoology at Syracuse University, Syracuse, New York, since 1938, has made the study of fossil insects a hobby, he says, chiefly because certain groups have an obvious relationship to the transmission or causation of certain parasitic diseases. Dr. Manwell is a graduate of Amherst College and received his Sc.D. in malariology from Johns Hopkins University.

POMPEII and Herculaneum are famous in human history because of the great disaster that overtook them in the catastrophic eruption of Mount Vesuvius in A.D. 79. But the tragedy that suddenly snuffed out the lives of so many Romans proved good fortune, of a sort, for posterity. Had not those prosperous Italian cities been so suddenly overwhelmed and buried by the mud and ashes from the angry volcano, we should certainly now know much less of Roman life of the first century.

Few people are aware of a similar series of catastrophes that befell a small segment of the insect world some 25 million years earlier in central Colorado. In Miocene times, long before the Rocky Mountains reached their present majestic height, there occurred in that area a number of volcanic eruptions. One of the volcanoes, of which little trace remains today, was situated near what is now the little hamlet of Florissant, a community too small even to keep the railroad it once had. About 30 mi west of the town is Pikes Peak, and not far to the west of that, the Continental Divide. Florissant itself is now about 8200 ft above sea level. But in Miocene times its site was much lower, and the climate was apparently subtropical and moist, since the fossilized remains of palms and sequoias have been found there. Nearby was a beautiful lake, although evidently a small and shallow one. High promontories reached out into it, and there were a few islands which must have added to its beauty. In more recent times the whole area has tilted sharply toward the northwest, with the result that the lake was drained dry, much as one might empty a saucer.

But the volcanic eruptions that created so much havoc to myriads of insects, and no doubt to other life of the region as well, occurred long before the lake itself disappeared, to become what we might call a fossil body of water. Instead of the great outpouring of mud and ash that inundated Pompeii and Herculaneum, there must have been successive showers of much finer dust, interspersed with occasional coarser material. Whether the insects were first killed by toxic gases, such as the hydrochloric and hydrofluoric acids often present in volcanic emanations, or were simply carried down by the heavy dustfall into the waters of the lake, we shall never know. Doubtlessly similar events have happened many times in other parts of the world, both in the distant and more recent past, and are still happening.

But conditions at Florissant were different. There, under the quiet waters of the lake, the gradual transformation of the volcanic debris into the soft and delicately layered shale that we find today began. On these sheets of rock, some of them almost paper-thin, we find inscribed a kind of pictorial history of the insect and plant world of that remote time. Many of these luckless creatures left fossil imprints exhibiting a perfection of detail surpassed only by the equally famous fossil insects found in Baltic amber (*1*).

That animals so small, and with bodies as delicate as those of many insects, should leave any fossil remains at all is remarkable, and such fossils are known in abundance from only a few localities. Although probably few of its tiny population realize it, Florissant is famous throughout the entire entomologic and paleontologic world for its insect graveyard. The scientific value of these remains is enhanced not only because they are representative of a very different region, but also because they are of a quite different period from the older fossils found in Baltic amber. The latter are believed to be of the Oligocene period, and the former are regarded as Miocene. Thus, some 15 million years may separate them, and Florissant fossils are perhaps 25 million years old.

The shales formed from the volcanic detritus accumulated to a depth of at least 45 to 50 ft, but much of the original deposit has long since been eroded away, and by no means all its layers contain insect fossils. Some of the strata show only

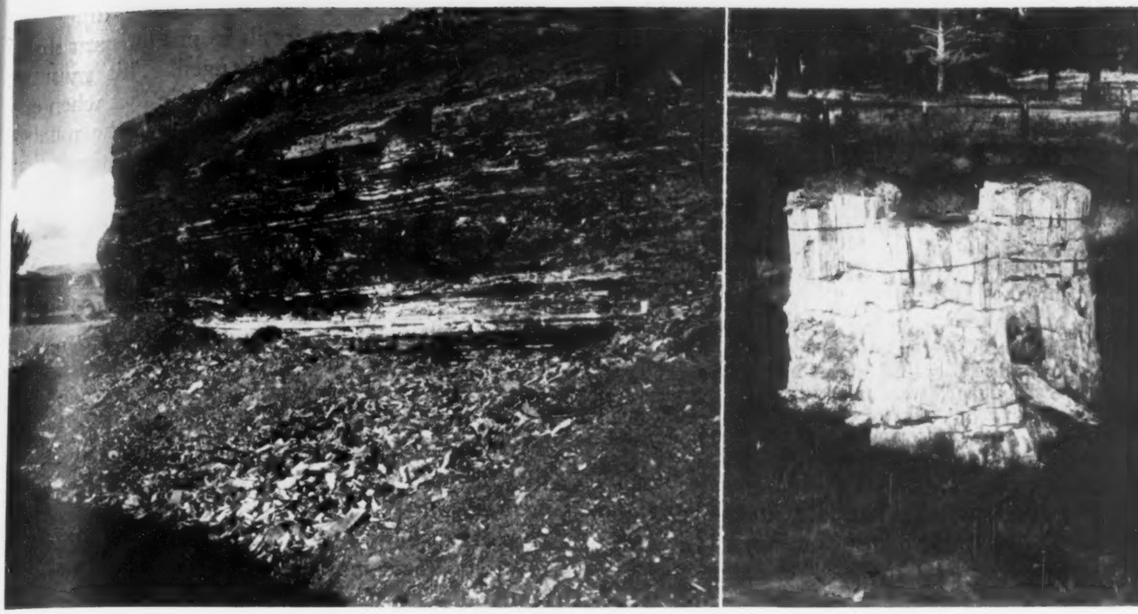

Fig. 1. A section of the quarry in the Colorado Petrified Forest and Pike Petrified Forest where most of the fossil insects that provided the subject of this article were collected. Layering of the deposits is well shown. Most of these layers are subdivided into thinner ones, some almost paper-thin, giving them the name "paper shales." Each represents either a separate volcanic eruption, or a phase of one, and their fossil content varies widely. Some contain fossilized insects in considerable abundance, but others contain few or none. Plant remains are much more plentiful than are those of insects. Fig. 2. A cluster of three fossilized sequoia trunks.

charred bits of wood and twigs or beautifully delineated leaves. There are also a number of petrified sequoia trunks in the near neighborhood, some of which are said to have been 12 or 15 ft high when discovered. Now, because of the toll taken by souvenir-hunting tourists, most are scarcely 3 ft above the ground, or are only just visible. The largest of them was from 10 to 12 ft in diameter.

Why there is so much variation in the type and abundance of fossils in different layers is hard to say. Perhaps it is partly because the volcanic eruptions occurred in different seasons of the year. Each layer of shale must represent a different outburst, or phase of an eruption.

The fossil hunter, if he is interested in doing his own exploration, may hunt for outcrops of shale and then break away pieces with a light pick or geologic hammer. But the material weathers so quickly after exposure that it is often better to take advantage of the fossil quarries already established, the owners of which are very courteous in their treatment of scientists. In either case, it is necessary to use a good deal of patience. Insect remains are not like those of dinosaurs. They often require the use of a good hand lens to make them out clearly, although there are compensations. They are much more likely to be found intact and do not require reassembly, as do dinosaurs, although in either case, of course, only the skeletal parts are preserved.

The shale, however, is likely to crumble after drying—it is usually moist when first uncovered—and it must be handled with care. A protective coating with some substance such as shellac prevents peeling and chipping and makes the finer structures much more visible.

Although insect remains are by far the most numerous of the animal fossils preserved at Florissant, other groups are also represented. The shells of tiny fresh-water mollusks are not difficult to find entombed in the rock, and, occasionally, even the skeletons of fish and birds are seen. Several hundred species of plants have been identified from these shales, usually from leaves, but fruits (that is, nuts) and even blossoms have also been found. Among the types recognized have been sequoias, palms, oaks, conifers (other than the sequoias), maples, elms, roses, and various legumes. It is said that the plant types collectively suggest a climate similar to that now found on the more northern shores of the Gulf of Mexico.

Insect life around and above Lake Florissant must have been very abundant, for it is not unusual to find on a single small piece of shale from one of the richer fossiliferous layers several individuals within 2 to 3 in. of one another. This

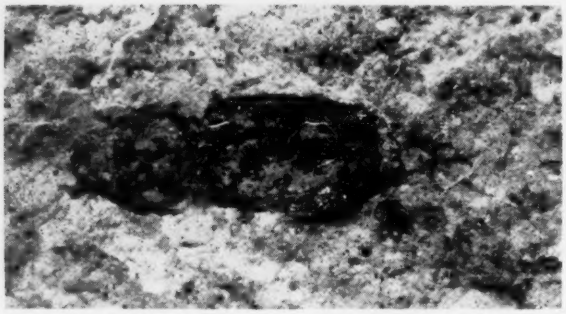

Fig. 3. A beetle of the family Tenebrionidae. Some of the members of this family are important today as destroyers of stored grain. Most are scavengers. (×7) [Figures 3 through 13 were taken for the author by Stella Zimmer, department of photography, the Medical School of the State University of New York, at Syracuse University.]

life was also extremely varied, with the total number of species running into the hundreds. Most of the larger orders of insects are well represented. Samuel H. Scudder (*2*), who made some of the earliest and most thorough studies of the Florissant fossil insect fauna, prepared a comparative tabulation (Table 1). Members of other orders also occur. For example, occasional specimens of Odonata (dragonflies and damsel flies) are found.

It is rather difficult to compare the relative abundance of these groups today with that of Miocene times, some 20 or 25 million years ago, because to make an accurate comparison would involve finding an existing environment just like that of ancient Lake Florissant. Essentially, however, it appears that the insect world has changed relatively little in that vast period of time. All but one of the presently existing 25 orders were then in existence, and most of them were already very ancient (*3*). No one can say just when the first insects appeared, but fossil forms (much like some we know today) have been found in rocks of the Upper Carboniferous (late coal-forming) period, dating from about 200 million years ago.

Numerous genera and species have become extinct, and the distribution of others is much different from what it was in Miocene times; yet many forms known as fossils from Florissant shales still survive virtually unchanged. This must be considered an especially remarkable fact when one recalls the short life-span and, hence, the number of generations there must have been since that remote epoch.

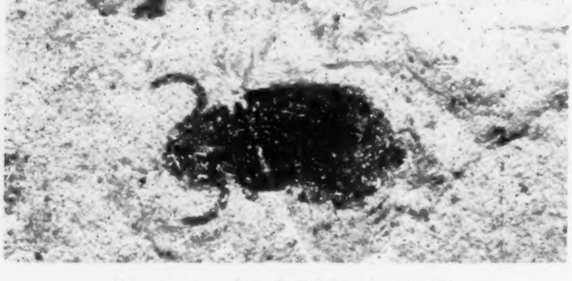

Fig. 4. Another fossil beetle. (×7)

Nevertheless, it seems certain that some groups were more numerous then than now. Scudder (*2*) commented on the "prodigious number of ants" (about 25 percent of the total) represented in the insect fossils of Florissant, and the true flies (Diptera) were the second most commonly encountered group. Today the beetles (Coleoptera) vie with the flies for the distinction of being the largest insect order, although in North America it is said that there are some 25,000 species of the former as against only 15,000 of the latter. The relative abundance of the two at Florissant was therefore reversed. But it must be remembered that climatic conditions in Miocene Florissant were quite different from those in most of North America today. Doubtless the season of the year when the eruptions occurred was also a factor in determining the relative abundance of different groups. It has been suggested that the eruption that resulted in the deposition of the richest fossiliferous layer may have occurred in the spring, because of the nature of some of the plant remains and the abundance of March fly (bibionid) fossils.

Not only have insects apparently undergone little structural change in many millions of years, but also their habits, at least in many cases, remain much the same. This is indicated by many similarities, both in form and type, to closely related groups today. The ants were divided into castes then as now, with winged reproductive forms and wingless workers. There were also many chalcids—often called flies but really tiny wasps—a family in which most of the members, during their larval stages, parasitize other insects. In some modern

Table 1. Relative abundance of major insect or arthropod types in Florissant volcanic shales.

Order (or subclass)	Representative types	Percentage of total
Hymenoptera	Ants, wasps, bees	40
Lepidoptera	Butterflies, moths	0.04
Diptera	True flies	30
Coleoptera	Beetles, weevils	13
Hemiptera	True bugs	11
Neuroptera	Dobson flies, lacewings	5
Orthoptera	Grasshoppers, roaches	0.25
Arachnida	Spiders, ticks, mites	0.25
		99.54

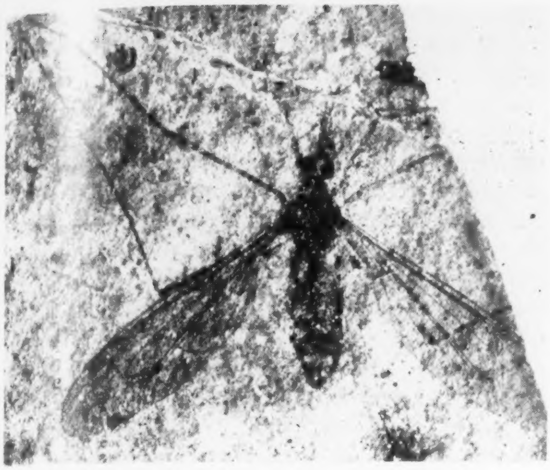

Fig. 5. A fossil crane fly. In the original specimen, even the individual facets of the eyes are visible with a hand lens. Crane flies are often abundant about meadows or bodies of water such as Lake Florissant must have been. (×3)

species (and hence, very likely, in some of these fossil types) the chalcid larvae even parasitize other parasites.

Then there were the ichneumon and braconid flies, actually like the chalcids in also being wasps. Both types parasitize other insects and play a very important role in the maintenance of biological balances.

It is also certain that warble flies were abundant. Their larvae feed on mammals, in the flesh of which they develop until ready to pupate. Fossilized warble fly larvae and pupae, presumably dropped from some mammalian host, have been found in shales even older (Eocene) than those at Florissant in both Colorado and Utah. These must surely be among the oldest fossilized internal parasites known.

Among the true flies that seem to have been abundant about Lake Florissant were also the mosquitoes, Culicidae, and the midges, Chironomidae, although unfortunately so far almost no forms of either group have been found showing wings. Nor have fossil larval stages of either been seen yet, although they must have been present in great numbers in the shallow waters close to the reedy shores.

The presence of mosquitoes makes one wonder whether mosquito-transmitted diseases, such as malaria, already plagued the terrestrial vertebrates of the world. Birds were certainly numerous, and malaria is a very common infection in many avian species, particularly the perching, or passerine, types, fossil remains of which have been found in the Florissant shales. There had presumably been ample time for the malarial parasites to have evolved their present mosquito-vertebrate cycle, for mosquitoes are known from Eocene times, 35 million years, more or less, earlier than the Miocene period.

In this connection, it is interesting to speculate about how and when malaria originated. Even today, with all that has been accomplished in some countries toward its control by the use of DDT, malaria is still probably the most prevalent of human diseases. The malarial parasites that attack the lower animals are of different species from those that attack man, but this group of parasites (genus *Plasmodium*) are all very closely related.

Perhaps the malaria plasmodia were first parasites of mosquitoes. Later, after being introduced into vertebrates in the process of bloodsucking, some of these parasites proved adaptable enough to continue life in their new environment and yet have retained the ability to live in the mosquito host whenever opportunity came. Thus the typical mosquito-vertebrate cycle may have originated.

Perhaps reptiles were the first vertebrate hosts of malaria, especially since they are still subject to infection by various species of plasmodia. Birds and mammals both evolved from reptilian stock and

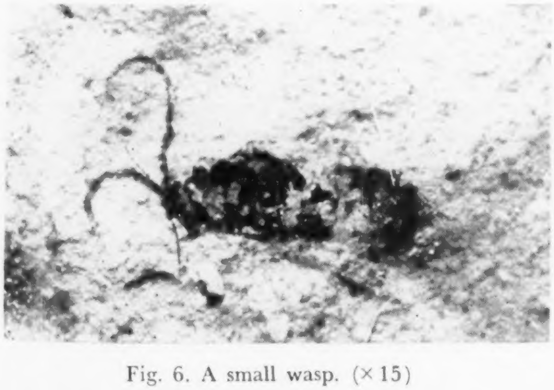

Fig. 6. A small wasp. (×15)

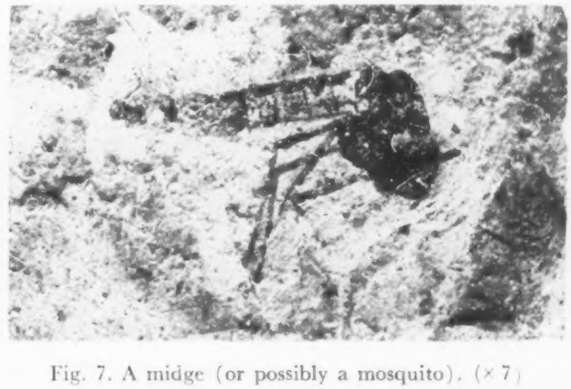

Fig. 7. A midge (or possibly a mosquito). (×7)

Fig. 8. An ichneumon fly (wasp). (×10)

Fig. 9. A bibionid fly (March fly). (×6)

Fig. 10. Fossil nut (very likely a pecan). (×3)

thus, in a manner of speaking, very likely inherited malaria from their saurian ancestors. But it is certain that neither man nor any of his simian and anthropoid relatives suffered from malaria inflicted by mosquitoes breeding in ancient Lake Florissant, since no primates existed there at that time.

Disease, however, is undoubtedly as ancient as life. Indeed one might say that disease is almost a biological necessity, for without it the delicate balance that exists between all living things and their environment would be much more difficult to maintain. Famine and even more ruthless competition than already exists in nature would have to take over the role of the pathogenic parasites. That such parasites have existed for a very long time is suggested not only by the great antiquity of mosquitoes but also by the discovery of fossil tsetse flies of Miocene age in Florissant shales. At present the latter are restricted to equatorial Africa, where they are of great importance as transmitters of human sleeping sickness (trypanosomiasis) and some closely related diseases in domestic and wild animals.

One cannot but wonder whether some of the numerous species of mammals then living in North Africa, and now extinct, may not have perished from the earth as the result of similar tsetse-borne diseases. It is also tempting to speculate on how different the history of the New World might have been if these flies had remained as widespread in their distribution as mosquitoes still are, for civilization and diseases such as the trypanosomiases of man and domestic animals simply do not mix.

We can only guess at the factors that may have caused the range of the tsetse fly to contract to its present much more restricted area. Quite possibly, it was the repeated glaciation that covered so much of the temperate regions of the Northern Hemisphere and greatly changed the climate even where there was no ice.

Fossil deposits such as those of Florissant not only intrigue the imagination, when we try to picture the world, so far off in time, that existed then but also perhaps raise more questions than they settle. Not only does the finding of fossil insect types that are now important as vectors of disease-producing parasites make one wonder whether they played the same role then, but it poses many other questions about evolution. How rapidly do new species, genera, families, and larger groups evolve? Why do some types apparently evolve more rapidly than others? Did evolution occur faster in some geologic periods than in others?

From the biologist's point of view it is most unfortunate that so little attention is being given to the study of insects of the past. Although it is virtually certain that the insect fauna of more remote geologic time was at least as varied and abundant as that of today, only some 13,000 fossil species are known from the entire world. A more complete knowledge of insect fossils would shed much more light not only on the evolution of that group but on other problems (such as those of climatic changes) as well.

We may also wonder whether insects have evolved more rapidly—or less rapidly—than mammals. The former are more ancient by at least some 60 million years, since the oldest known insect fossils (but certainly not the first insects) date from the Upper Carboniferous (coal-forming) period, which ended about 220 million years ago. There are also far more species—at least 1 million of insects, as against possibly 5000 of mammals. Some 3000 more of the latter are known as fossils.

Although the insect world in Miocene times, as revealed by the fossils in Florissant deposits and those from other deposits of like age, was not very different from that of today, the mammalian fauna would have presented a sharp contrast. No North American series of mammalian fossils of just the same age as the Florissant insect remains is known, but we do know that most of the genera of mammals existing then are now extinct. Instead of the familar species of the present, hyenas, rhinoceroses, camels, wild horses, and elephants might have been seen. Perhaps there were still even a few of the great titanotheres, mammals of immense size and now wholly extinct, ranging the plains and grassy uplands. Man, of course, did not arrive on the scene until perhaps 1 million years ago, and did not reach North America (according to George Carter of Johns Hopkins University) until, at the most, perhaps 100,000 years ago—hardly yesterday to a biologist.

The study of the records of a time so long ago that we cannot even call it a forgotten epoch thus sheds light on many important problems of the present but raises more problems than it solves. For life is a kind of clock and, like all clocks, refers only to the present, but has meaning only in terms of the past, since the future cannot be known. What time may hold in store for the insect world, for mammals, or even for man, the records of past ages only hint. But whether the human species has a long future ahead, or whether—like the titanotheres that vanished after millions of years of apparent success—it is destined to early extinction, we may be sure that, until the end, man will continue to be fascinated by the story told in ancient rocks, such as the volcanic shales of Florissant.

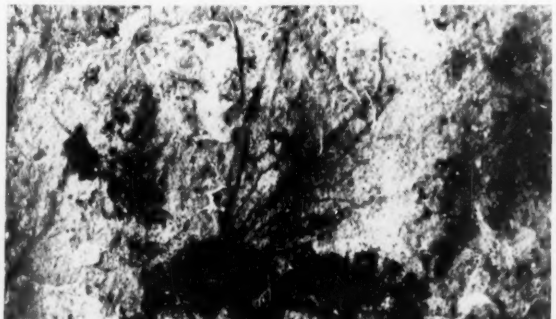

Fig. 11. Winged ant. (×5)

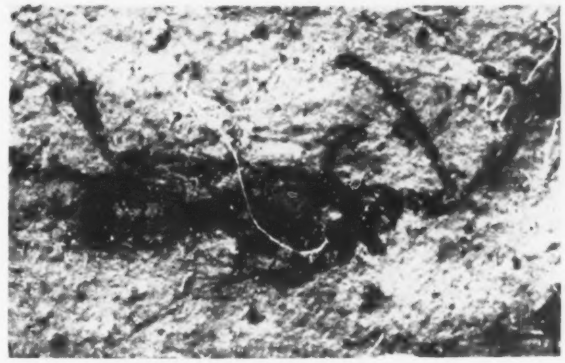

Fig. 12. Parasitic wasp. (×17)

Fig. 13. A rove beetle. The rove beetles, Staphylinidae, are mostly scavengers and are good runners. (×8)

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Spontaneous Activity and Behavior

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EVERYONE whose training has included elementary zoology has been exposed to the spinal reflex, or reflex arc. A little later the association between the reflex and behavior is reinforced by meeting the conditioned reflex in a course in psychology. Certainly there can be no simpler introduction to central nervous system function and behavior than through the work of Sherrington and Pavlov; but it seems that this experience, often amounting to the literal and thankful acceptance of a concrete concept in a confusing field, produces a fixed idea that may become an actual hindrance if the student eventually finds himself concerned professionally with the behavior of animals and men.

The Reflex

The term *reflex* implies a simple, often linear, relationship between stimulus and response, and it is in the very simplicity and predictability of this relationship that the pedagogic attractiveness of the reflex concept lies. It is easy to teach and to understand. However, as the nervous system becomes more complicated, behavior becomes less "spinal" in nature; animals become less predictable in their activities, and no amount of summation of their various reflexes leads to an understanding of behavior.

The inadequacy of the Pavlovian conditioned reflex as a unit of behavior is recognized in psychological studies of learning, and it is now considered to be a special case. Conditioning associated with a response toward food or away from a painful stimulus is thought to be possible because of a tendency of the subject to seek an environment of optimum comfort. Psychologists have expanded Cannon's homeostasis to include this behavioral tendency to seek an equilibrium state. Implicit in this view, as in the reflex concept, is the assumption of no (painful) stimulus—no motion. Yet, it seems to be the rule, rather than the exception, that the satiated rat proceeds to explore other turns in the maze through which it has run so recently under the drive of hunger.

Many years of teaching neurophysiology along Sherringtonian lines, research on the insect nervous system in which spontaneous nerve activity is practically universal, and observation of the unpredictability of most animal behavior have led me to seek a reconciliation of these apparently contradictory aspects of nerve activity and behavior.

Kinesis

An everyday observation which receives no explanation from the stimulus-response approach is that living matter, from its lowest form to its highest, never reaches "dead center" or static equilibrium with its surroundings. Achievement of a true steady state where input and output remain unchanged may be logically possible but simply does not occur in animals. There is either growth or involution, or, in the realm of behavior, activity or kinesis, even when ambient conditions are kept as constant as possible.

Many animals show taxes, or orientating movements, when placed in a gradient of light intensity, humidity, chemical, or other environmental condition. In most of the lower animals and some of the higher forms these taxes are extremely direct and reproducible. If the stimulus-response relationship of the reflex were the only mechanism at work under these conditions, the organism might be expected to become motionless and remain so, once the optimum point in the gradient had been reached. It is common knowledge that this does not occur, or if it does occur the state of inactivity, or akinesis, lasts only for a limited time, even though the dominant gradient remains unchanged.

Students of animal behavior have long recognized the ubiquity of kinesis, and recently Lorenz (*1*) and Tinbergen (*2*) have made a successful attempt to incorporate it into the fabric of their new approach to behavior known as ethology. Lorenz uses the term ***appetitive behavior*** for the restless, unorientated behavior (search behavior) which is the outward sign of a mounting internal drive. Appetitive behavior exposes the organism to a random sequence of sensory patterns, one of which, under natural conditions, may orientate the organism toward a situation that permits the consummatory act. Following consummation, appetitive behavior falls to a low level, and akinesis prevails until the development of the same, or of another, drive is signaled by increasing kinesis.

One explanation of this restlessness of living matter is that changes in internal chemical factors, such as nutrition or sex hormones, increase the susceptibility of the central nervous system to previously ineffective input from receptors for chemical and physical gradients in the environment. Whereas such an increase in susceptibility undoubtedly occurs, there is no evidence that the organism shows a taxis, or orientation, during appetitive behavior, movements being apparently quite random. In fact, appetitive behavior may be said to terminate as soon as there is a definite orientation toward, for instance, food or mate. Another possibility is that heightened sensitivity may permit a response to sensory cues, which are nevertheless too faint or diffuse to provide a basis for definite orientation. With regard to these two possibilities the senses could be considered to play a double function in behavior: (i) as the input of specific information within each of their modalities; (ii) as nonspecific contributors to the general level of excitability of the organism.

As nonspecific contributors to excitability, the senses probably play a part in kinesis. However, it does not seem possible to arrive at a physiological understanding of kinesis by consideration of the senses alone. Almost continuous activity punctuated only briefly by clear-cut orientation is found commonly in the simplest animals, such as the coelenterates. Extensive studies of the physiology of slow rhythmic contractions of the body in sea anemones have led Pantin (*3*) to conclude:

> But whatever the origin of this activity it appears to be inherent in the animal and not initiated by causal external stimuli.

Reduction in the total sensory input may actually increase activity, as in nocturnal organisms. Experimental removal of major sensory ganglia in insects may increase kinesis to the point where it becomes continuous, as is shown in the following sections. Periods of activity and quiescence continue to alternate in organisms kept for long periods under the most carefully controlled and constant laboratory conditions. In short, the stimulus-response relationship, which is such an important aspect of the reflex, does not explain kinesis, and we must search elsewhere for a physiological mechanism.

Spontaneous Activity

The failure of reflex physiology to provide a basis for behavior derives mainly from the assumption that the elements of the reflex—afferent neuron, efferent neuron, and muscle—are completely "silent," or inactive, unless they are acted upon by a stimulus of sufficient strength. This seems to be essentially true of the simpler reflexes when they are isolated from the rest of the nervous system, the experimenter having complete control over the situation in his capacity to administer the triggering stimulus. It is certainly not true of a number of excitable systems, some of which must be expected to play important roles in behavior.

The vetebrate heart is probably the best-known of the organs that exhibit spontaneous or endogenous activity. It continues to beat regularly after its nerve connections with the rest of the organism have been severed and even when it is completely isolated *in vitro*. There is no reason to suppose that the excised heart would not continue to beat indefinitely if it were possible to correct metabolic defects due to the artificial environment. The tendency to beat must be regarded as an expression of normal instability in the excitable pacemaker and thus is truly endogenous and independent of external stimuli. This endogenous instability is, of course, subject to external regulation. It may be altered by changes in temperature, salts in the surrounding fluid, and a host of drugs. Natural regulation is accomplished by postganglionic sympathetic nerves, which accelerate the beat, and by parasympathetic nerves, which slow the heart.

Spontaneous activity of this kind is also characteristic of many types of smooth muscle and ciliated epithelia. Effectors that do not depend upon a stimulus-response mechanism for their normal activity are widespread and are in no sense physiological anomalies. The connection between such effectors and the problems of behavior may well be questioned, so let us now turn our attention to spontaneous activity in nerves.

Spontaneous activity in the central nervous system of invertebrates has been noted by many since Adrian (*4*) first described an asynchronous discharge of nerve impulses in the isolated nerve cords

of a caterpillar and a beetle. Electrodes placed on the excised chain of ganglia that form the central nervous system of the cockroach register a steady but asynchronous sequence of electric pulses (*5*). These pulses have the same duration and magnitude as the spike potential, which is the electric sign of the nerve impulse in a stimulated nerve fiber, and there seems to be no doubt that they are traveling back and forth in various nerve fibers within the nerve cord. Although they are detected in the connectives between the segmental ganglia of the central nervous system, the potentials cease if the connectives are severed from the ganglia, and they appear to originate in the cell bodies of neurons located within the ganglia. The asynchronous character of the activity seems to be due to the independent discharge of impulses in a large number of neurons. Analysis of spontaneous activity shows that each neuron may discharge quite regularly at its own frequency.

If it is maintained in physiological saline containing glucose and oxygen, the cockroach nerve cord may continue this spontaneous discharge for as long as 50 hours. As the preparation deteriorates, the neurons cease their activity one by one, and the electric pattern becomes progressively simpler. The level of spontaneous activity is readily altered by various drugs, the salt content of the saline, and the amounts of oxygen and carbon dioxide present. In fact, it is more sensitive to chemical changes in the surrounding fluid than is the process of synaptic conduction in the same nervous system.

Prosser (*6*) has described a similar situation in the isolated central nervous system of the crayfish, and nervous activity in the complete absence of afferent supply seems to be quite general in the nervous systems of invertebrates. Many invertebrate neurons appear to be normally or inherently self-exciting, spontaneous activity being present immediately following separation of the nervous system from the sensory nerves, even while the nerve cord still lies in its natural environment—the body fluids.

The extent to which spontaneous activity occurs within the deafferented central nervous system of vertebrates has not been so fully explored as in the invertebrates. To some extent this is due to the greater concentration of nerve cells into a compact spinal cord and brain and the need for an unimpaired circulation and respiratory mechanism for normal function—factors that make complete isolation of nerve tissue from sensory input a difficult surgical feat in vertebrates. The isolated forebrain (which contains the precursor of the cerebral cortex of higher forms) of the frog continues to discharge rhythmic waves at a dominant frequency of six per second for 3 hours after removal (*7*). Libet and Gerard also showed that changes in the relative proportions of salts in the saline cause marked alterations in the frequency of the rhythm.

Studies of spontaneous activity in the mammalian central nervous system have encountered still greater technical difficulties. However, according to Dunbar and Gerard (*8*):

> The normal spontaneous rhythms of the cat's geniculate body, especially the dominant one at 3 per sec., are independent of impulses reaching the neurones from optic nerve, cortex, or brain stem. The background level of excitation, determined largely by optic impulses, however, strongly influences their character. The slow rhythm fades out after hours in the dark, and is reinitiated after brief illumination.

Similar observations have been made on the cerebral cortex of mammals. Kristiansen and Courtois (*9*) found spontaneous activity in neurologically isolated slabs of the cat's cerebral cortex. They concluded that rhythmic activity closely allied to the alpha rhythm is an inherent property of the cortex. This activity is not dependent upon thalamocortical connections, although the latter may modify its form and amplitude. Bremer (*10*) is of a similar opinion regarding the origin of cerebral rhythms. On the other hand, Burns (*11*) found no spontaneous activity in a neurologically isolated slab from the suprasylvian gyrus of the cat's cortex. He was able to elicit by direct electric stimulation a series of discrete, prolonged electric responses that continued to spread from the stimulated point for many minutes after the stimulation had stopped. An interesting characteristic of the prolonged response was a surface-positive wave lasting several seconds, accompanied by a prolonged asynchronous discharge at a frequency of 65 to 75 per second in a deep-lying layer of cortical cells. Burns concluded that the surface-positive wave is due to self-reexcitation in small (2-mm diameter) closed chains of deep-lying neurons. The cause of eventual failure in these self-reexciting chains and, hence, the failure of the activity to continue spontaneously may be due to gradually rising refractoriness, which eventually exceeds the circuit time in the loops.

The difference in the presence (*9, 10*) or absence (*11*) of activity in the neurologically isolated, unstimulated cortex is probably not very significant. All of these workers maintained an intact circulation to their preparations, and they have emphasized the great sensivity of cortical activity to slight chemical changes in the blood stream. Burns' results indicated instability very close to spontaneity. His failure to observe a self-perpetu-

ating rhythm could well have been due to a subtle difference in the state of his preparation or in the blood supplying it. It is of interest to note that Bremer is of the opinion that cortical activity depends upon "synchronized cellular pulsations" similar to those responsible for spontaneous activity in the aforementioned invertebrate nervous systems and not upon the closed reverberating loops of nerve cells, which have been commonly invoked as a mechanism in vertebrates (*12*).

It is perhaps surprising to learn that many peripherally located sense cells show spontaneous activity. Electrodes placed on the sensory nerve fibers from various mechanoceptors and chemoceptors on the leg of an insect register a steady discharge of impulses, even when the leg is completely motionless. Some of this activity probably originates in slowly adapting mechanoceptors under a residual amount of mechanical stress, but no condition has been found in which, after amputation of the leg or nerve section, sensory discharges cease entirely. There seems no reason to doubt that much of this activity is a "rest" discharge that continues indefinitely under conditions approaching zero stimulation.

Spontaneous activity occurs also in the modified mechanoreceptors that constitute the lateral-line system of fishes. In discussing the evolution of hearing in vertebrates Pumphrey (*13*) suggests a neat correlation between this spontaneous activity and the extremely small amounts of energy required to stimulate the lateral-line and cochlear sense cells. He concludes that spontaneously active cells must have no true threshold. Their excitability must change continuously, during one cycle of activity, from complete refractoriness at the time of discharge to complete excitability, or instability, just before the next discharge. In between these extremes of excitability spontaneously active cells must become progressively more and more excitable (sensitive to an energy change or stimulus from without) until a very small stimulus is able to trigger the discharge a little sooner than it would have taken place spontaneously. The full significance of this idea is considered in the following section.

Neurophysiological Basis of Spontaneous Activity

It is not difficult to show that there is only a difference of degree between a nerve cell that is normally spontaneously active and a nerve cell that is normally inactive unless stimulated. By changes in the immediate chemical environment, it is possible to convert one type of activity into the other.

The isolated sciatic nerve of the bullfrog is classical material for the study of the stimulus-response relationship. It consists of a bundle of several hundred axons completely separated from their peripheral end-organs and central cell bodies. The sciatic nerve fibers are normally completely inactive unless stimulated, when a self-propagating compound action potential—the summed electric responses of the numerous fibers—is elicited by each effective stimulus. By definition, subthreshold stimuli are those that fail to elicit propagated responses, although it can be shown that they still cause small local changes in excitability in the vicinity of the stimulated region.

Changes in the calcium content of the fluid surrounding a nerve have a pronounced effect on the excitability of its fibers (*14*). A large number of the fibers in the sciatic nerve begin to discharge spontaneously if the preparation is bathed with a saline that lacks calcium or contains sodium oxalate. Each spontaneously active fiber appears to be discharging more or less independently of its neighbors, although there may be some interaction. Once initiated in a particularly unstable region, the impulse appears to be propagated in normal fashion over the length of the fiber, leaving a trail of temporary refractoriness. Progressive recovery from the depressed state continues until some region reaches the point of extreme instability and a new impulse arises. Pacemaker regions are presumably those that are the first to reach the condition of self-excitation.

Spontaneous activity may continue in the sciatic nerve for many hours. It may be stopped by returning the nerve to a saline solution containing the normal amount of calcium, and restarted once more by a return to the calcium-free solution. If a nerve, in calcium-free saline, is allowed to retain its motor connections with its muscle, the latter, even when in normal saline, will be thrown into tremors and fibrillation, owing to the incidence of asynchronous impulses at the motor end-plates. It is of interest to note that the abnormally low blood calcium associated with parathyroid tetany appears to be responsible in like manner for the tremors and convulsions that are characteristic of this condition.

The spontaneous activity normally present in the invertebrate central nervous system may be completely stopped by a different type of change in the ionic environment. If the ventral nerve cord of the crayfish is placed in physiological saline containing 2 to 4 times the amount of potassium normal to the blood, all spontaneous activity ceases (*15*). After as long as 30 hours in high-potassium saline a return to saline with potassium content similar to that of the blood brings about an imme-

diate return of spontaneous activity. There is no evidence that the neurons are damaged by this treatment, for, because of their inactive condition, they may survive even longer than those kept continuously in saline similar to the blood in salt content.

Thus neurons that, while in their normal environment, are inactive unless stimulated may be made spontaneously active, whereas neurons that are normally spontaneously active may be rendered inactive. Both effects appear to be completely reversible and are brought about by chemical changes in the surrounding medium. The transition from one state to the other seems to be merely quantitative in nature—a fact that should make it easier to reconcile the stimulus-response state with the state of spontaneous activity. Before this reconciliation is attempted, it is necessary to examine more closely what is meant by excitability.

The excitability of a nerve cannot be defined in physicochemical terms. The only way in which it can be made manifest and measured is by determining the minimum energy change, within a certain time interval and in a certain direction, that must be applied before the nerve will discharge an impulse. If an electric stimulus is used, the energy change is expressed in terms of electric current and the direction in terms of potential sign. Thus, we can say that the excitability or its reciprocal, the stability, of a nerve is proportional to the energy needed to abolish it, but we are unable to define it as a continuous property of the living tissue. Analogous reasoning is used in describing the stability of a building or other structure. In this case stability is expressed in terms of the force (pounds per square foot, wind velocity) that is just sufficient to cause its collapse, as compared with the force to which it is exposed under normal operating conditions.

The relationship between the excitability changes in a stable nerve and those in a spontaneously active nerve is depicted in the lower graph of Fig. 1. The vertical axis represents excitability, which in practice would be measured in units of stimulus strength. The lower horizontal line represents the rest excitability of a relatively stable nerve such as the sciatic nerve; it corresponds to the normal operating load in the building analogy. The upper horizontal line represents the threshold excitability or the load at collapse in the building analogy. The solid curve shows the sequence of excitability changes that follow exposure of a stable nerve to a momentary stimulus of the dimensions of S_1. It can be seen that the excitability (or instability) increases rapidly from the rest level until threshold excitability is reached. In the building analogy this is the moment of collapse; in the nerve it is the moment of propagation of the impulse, the outward sign of which is the all or none electric change or action potential (upper graph). During the impulse the excitability of the nerve drops to zero, the absolute refractory period; in the building analogy collapse is at this moment complete. From this point the nerve departs from the building analogy, since its metabolism enables it to return to its former state. The subsequent course of events varies in different nerves, but in large vertebrate A fibers excitability not only returns but overshoots the resting level, leading to a phase of supernormal excitability. As is shown in the solid curve, this is followed by a relatively prolonged subnormal phase of excitability and eventual return to the rest level.

The supernormal phase of excitability is of particular interest, since it provides a link between the stable and spontaneously active states of nerve. There is considerable variation in the relative magnitude of the supernormal phase, or, in other words, in the relative values of resting and threshold excitability. If the supernormal phase is relatively large or the difference between resting and threshold excitability is small, then the sequence of excitability changes must follow the dashed curve. As the rising excitability reaches the threshold level during recovery, the fiber becomes self-exciting, and impulses follow one another at regular intervals (Fig. 1, upper graph). Each impulse is accompanied by absolute refractoriness and followed by relative refractoriness and supernormal excitability

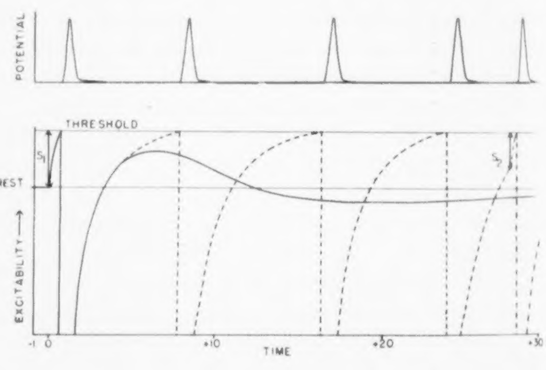

Fig. 1. (Lower graph) A comparison of the excitability changes in stable (stimulus-response) and unstable (spontaneously active) neural elements. Solid curve represents excitability sequence in elements such as mammalian A fibers following stimulus S_1. Broken curve represents predicted excitability sequence in elements with a lower threshold and, hence, repetitively active following stimulus S_1. S_2 is the stimulus interpolated at some point in the spontaneous excitability change and causes premature discharge. (Upper graph) Nerve impulses that would arise from the excitability changes shown below. Time units would have different values for different types of excitable tissue. In the case of mammalian A fibers the units would be milliseconds.

rising the threshold level. Thus, a single stimulus may initiate a sequence of impulses that continues subject only to the counter influences of adaptation and fatigue.

In a sense, this activity could be considered as spontaneous activity, since the original stimulus that triggered a long succession of impulses could readily be overlooked. Strictly speaking, it is repetitive activity. True spontaneous activity can be said to arise when the values for rest and threshold excitability (horizontal lines) coincide. At this point the nerve becomes completely unstable, and a similar succession of impulses begins without the need for any external triggering stimulus.

The suggestion by Pumphrey (*13*) that a spontaneously active fiber lacks a finite threshold is also illustrated in Fig. 1. A stimulus, S_2, may be interpolated at any instant during the excitability cycle of the fiber. If the stimulus occurs at the instant illustrated, it must be of the relative dimensions of the double arrow in order to bring the fiber to threshold within the utilization time. This leads to a propagated impulse and accompanying refractoriness somewhat earlier than it would have occurred spontaneously. The later its appearance in the excitability cycle, the smaller the critical size of S_2, and the smaller the effect that it would have on the frequency of the rhythmic discharge. On the other hand, a stimulus of the dimensions of S_2 would be completely inadequate if it occurred at the instant of S_1. Therefore, the sensitivity of the spontaneously active nerve element, frequency-modulated as it is by stimuli of all dimensions, is limited only by the capacity of central nervous mechanisms to detect small changes in the frequency of its rhythmic discharge.

It may be concluded, then, that there is no logical difficulty in accounting for the physiological basis of spontaneous activity. Its presence or absence in the same nerve element need depend only upon the difference between resting and threshold excitability. This difference is notoriously susceptible to chemical factors in the immediate environment of the nerve, some of which have been mentioned in the foregoing sections, as well as to changes associated with fatigue and adaptation within the nerve itself. It might be expected that the difference between resting and threshold excitability of many central neurons would be affected by subtler and slower changes in nutritional state and endocrinal balance.

Adaptation and Disadaptation

Another aspect of nerve excitability that certainly plays a part in spontaneous activity is the tendency of nerve elements to become increasingly less sensitive upon constant stimulation. The phenomenon of sensory adaptation is so well known that it is unnecessary to give specific examples. The drop in excitability that accompanies constant stimulation may be measured in milliseconds or in minutes, depending upon the type of nerve or receptor. In the terms of Fig. 1, adaptation can be considered as a tendency for the threshold excitability (upper line) to rise, or to diverge further from the resting excitability (lower line). A similar process, known as accommodation, occurs locally in a nerve fiber when a constant, but subthreshold, stimulus is applied.

The neurophysiological indication of adaptation occurring in an excitable element exposed to continuous stimulation is the steadily declining frequency of impulse discharge. The internal process of adaptation can be considered to work counter to the external stimulus in an excited sense organ or nerve, and it must also be supposed that adaptation works counter to the tendency to rhythmic discharge in a spontaneously active element. However, since adaptation can be measured only in terms of the onset, strength, and duration of the stimulus, there seems to be no logical way to measure adaptation in spontaneous activity. All that can be said is that, during a steady rhythmic spontaneous discharge, the tendency to adapt must just balance the tendency to self-reexcitation.

Of significance in the genesis of spontaneous activity is the inevitable, but rarely mentioned, reciprocal process of disadaptation. If a constant stimulus is withdrawn from a nerve element, a steadily increasing sensitivity must develop during the ensuing period of inactivity. In the terms of Fig. 1, the process of disadaptation can be visualized as a convergence in time of the lines representing resting and threshold excitability. If this convergence progresses to coincidence, spontaneous activity must be the outcome. Thus, a nerve element responding to continued stimulus in the manner of a stable fiber would become increasingly unstable or spontaneously active if the stimulus were withdrawn for a protracted period. Once spontaneously active, the excitability changes accompanying discharge would include some measure of adaptation, so that the eventual frequency of the spontaneous discharge would be determined by a balance between the adaptive tendency of activity and the disadaptive tendency of the intervening periods of inactivity. Reexposure to an external stimulus at this time could produce adaptation of a degree sufficient to terminate once more the tendency of spontaneous activity for some time.

It may be concluded that the tendency of nerve elements toward spontaneous activity must depend

not only upon chemical factors in the surrounding body fluid but also upon intrinsic factors, such as the previous history of activity and the tendency to adapt, or, rather, to disadapt. An experimental analysis of the interaction of these factors, predicted only on the basis of what is known about nerve excitability, would be of great interest, since the parallel between the behavior of nerve elements and animals is suggestively close.

Behavior and Spontaneous Activity

The foregoing attempt to weave fact and speculation into a significant pattern leads to the following conclusions. (i) The stimulus-response concept implicit in the reflex does not by itself provide an adequate basis for the description of behavior in physiological terms. (ii) Kinesis, or activity lacking a detectable external stimulus, forms a part of many behavior patterns in the majority of animals. (iii) Spontaneous activity, or self-reexcitation, is normal to many muscles and nerves. (iv) Spontaneous activity and the stimulus-response type of activity may differ only on a quantitative level. (v) Adaptation and its reciprocal, disadaptation, provide a means whereby a stimulus-response type of nerve element may become, in the continued absence of external stimulation, spontaneously active.

The circumstances of spontaneity in nerve elements are strikingly analogous to those of kinesis or appetitive behavior. However, it is very difficult to determine whether or not a casual or homologous relationship exists between these two types of biological activity. One of the first questions likely to be raised in this connection is whether spontaneous activity takes place in the central nervous system of an intact animal. There is no way to reach a firm answer to this question, since sensory input could account for central nervous activity in the intact animal, but the animal would no longer be intact if any sensory connections were severed. One can answer only by saying that there also seems to be no logical reason why spontaneous nerve activity established to occur *ex vivo* should not also take place *in vivo*. A few of the many attempts to relate spontaneous activity or lack of sensory input to functional behavior are discussed in this section.

One group of experiments have been concerned with the minimum afference or sensory input necessary for coordinated locomotor movements. The sensory fibers of vertebrates are concentrated in the dorsal roots of the spinal nerves. This makes it possible to sever all the sensory connections of the spinal cord without undue interference with its motor connections to the musculature. Such an operation necessarily produces considerable trauma and circulatory disturbance, so results obtained through it must be considered with some reserve. Gray (*16*) has reviewed much of the work along these lines. In toads it has been found (*17*) that coordinated locomotor movements in all four limbs are still possible when only one limb retains its sensory connections with the spinal cord. Coordinated swimming movements continue after complete section of all spinal dorsal roots, provided that connection with the membranous labyrinths remains intact. Similar results have been reported in fishes (*18–19*). In these experiments the minimum amount and variety of sensory input needed for coordination of the limbs is surprisingly small; nevertheless, it is Gray's conclusion, based on the need for afference from at least one limb or from the labyrinths, that the endogenous origin of locomotor rhythms remains unproved. On the other hand, von Holst (*18*) is convinced that the coordinated interaction of rhythmic activity in the body segments concerned in walking and swimming is a central process essentially independent of peripheral stimuli.

A more clear-cut situation is provided by the mechanisms that control respiratory movements. It is well known that the sequence of coordinated movements involved in respiration is regulated by the activity of a group of neurons comprising the respiratory center in the brain stem. The basic frequency of this activity is determined by the concentrations of oxygen and carbon dioxide in the blood stream, acting both directly on the neurons of the respiratory center and through chemoreceptors in the carotid sinus. Superimposed on this chemical control is the modulating effect of proprioceptors in the lungs, cold endings in the skin, and the higher brain centers. In terms of the preceding discussion, the respiratory-center neurons may be said to be inherently unstable under normal conditions of the blood stream and subject to frequency modulation by changing chemical conditions in the blood and by impinging afferent impulses. This is borne out by the observation (*20*) that electric activity in the isolated medulla of the goldfish continues in a rhythmic pattern corresponding to the respiratory movements of the intact fish. A similar rhythmic sequence of potentials occurs in the isolated nerve cord of the water beetle (*4*). The isolated nerve cord of the grasshopper shows a steady asynchronous discharge in well-aerated saline. However, when the concentration of carbon dioxide above the saline is increased to 5 percent, the potentials group themselves into a sequence of well-defined bursts which correspond.

in their timing, to the respiratory movements of an intact grasshopper under the same conditions. Respiratory movements cannot be considered as behavior of a very high order; nevertheless, the connection between spontaneous nerve activity and functional movement is fairly clear, and the parallel with more complex forms of behavior is most suggestive.

In insects elimination of the ganglia concerned with large segments of the sensory input may actually increase kinesis. This can be demonstrated because the insect brain serves mainly as the sensory ganglion for the special senses of vision, olfaction, and tactile sense mediated by the antennae. The results of various types of brain operation have been reviewed (*21*). In the praying mantis the orientation associated with feeding and courtship depends primarily upon vision. Under natural circumstances the praying mantis is a fairly inactive insect, remaining motionless on a twig for long periods. Removal of the brain leads to almost continuous coordinated locomotion (*22*). The brainless insect travels forward in a straight line for hours at a time and appears to be unable to avoid or to climb over obstacles. This continuous kinesis may cease temporarily, either because of entanglement with obstacles or because of exhaustion. If the insect is not completely obstructed, kinesis usually begins once more, either spontaneously or upon a brief tactile stimulus, and will continue again for a considerable period. It is concluded that centers in the brain or supraesophageal ganglion normally control centers in the subesophageal ganglion through some degree of inhibition. In the absence of this inhibition the subesophageal centers appear to be in a state of continuous spontaneous activity, probably augmented while the insect is in motion by input from proprioceptors at the leg joints.

The sexual behavior of the praying mantis (*23*) affords another example of increased motor activity after the removal of higher nerve centers. The mature male mantis recognizes the female by sight and approaches her slowly in a straight line. No copulatory movements of the long abdomen are seen until a quick jump or short flight has carried the male onto the back of the female. Body, and probably antennal, contact between the two immediately releases a series of search movements in the male abdomen. If the male and female are head to head these search, or appetitive, movements eventually lead to contact with the female genitalia, and copulation ensues. If the position of the male on the back of the female is reversed, the apparently random abdominal movements continue until physical contact is lost or the male assumes the normal mating position. Decapitation (or removal of the supra- and subesophageal ganglia) of the male, even when immature or not in contact with a female, immediately releases searching abdominal movements, which continue without pause for days. Even an isolated abdominal tip of the male, containing only the final ganglion of the chain, will show these unceasing movements, and it seems clear that they are due to spontaneous activity that is normally inhibited by nerve centers in the subesophageal ganglion and released only by specific sensory stimuli to the legs and antennae.

Continuous locomotion and copulatory movements of the abdomen in the mantis are of some interest, since they seem to correspond with what is usually known as appetitive, or search, behavior. Unfortunately, no way has been found to eliminate the remaining sensory input from the rest of the body, so that deafferentiation is incomplete. However, it may be concluded that the ganglia associated with the major sense organs of orientation actually inhibit the appetitive behavior. An experiment that would determine whether the appetitive behavior released under these circumstances was dependent upon other sense organs on the general body surface or was truly spontaneous would be of absorbing interest.

Conclusion

At this point you may have gained the impression that I champion spontaneous activity with the same measure of bias that I decry in the reflexologists. The point of view that lies behind this article may be expressed quite briefly. The physiological basis of behavior cannot be constructed merely from the summation or interrelationship of reflexes. Nor is this possible by the invocation of spontaneous activity alone. Since behavior cannot yet be described adequately in physiological terms, there are certainly many subtle characteristics of nerve cells that are unappreciated; yet a more workable approach to the problem is afforded by considering both the stable and the unstable states of nerve cells and nerve cell combinations.

Spontaneous activity in various nerve elements seems to be established beyond all doubt, whereas the transition from the stable stimulus-response state to the unstable spontaneous state can be understood by reference to the known properties of excitable tissues. The parallels between the behavior of nerve cells as they alternate between these states and the alternation of appetitive and orientated behavior in the intact animal are too striking to be ignored. The few examples given in the pre-

ceding section are recognized as quite inadequate to establish a firm connection and serve only to point up the main gap in the story—the lack of a direct experimental demonstration that kinesis and appetitive behavior have their origin in the spontaneous activity of certain nerve centers. However, this lack is not evidence either for or against the role of spontaneous activity in behavior but, rather, an invitation to research.

At the beginning of this article it was suggested that the tendency by some to discount the possibility of endogenous behavior might be due in part to early imprinting with the reflex idea. Perhaps this is due also to a belief that the concept implies that behavior originating from within is not susceptible to external influences or control. It is suggested that those who shy away from this possibility because it has for them supernatural overtones should do some reading on the physiology of the heart—a spontaneously active but certainly not supernatural organ. Others, in their concern with human affairs, may feel that the concept of endogenous behavior offers no practical *modus operandi* in their work. First, it must be repeated that the spontaneously active system combined with a sensory input is actually more sensitive to external change than is the conventional stimulus-response system (Fig. 1). Second, the spontaneously active system is, in addition, inherently more sensitive to a variety of constant or slowly changing internal conditions, such as blood chemistry, which are the products of previous and long-term environmental circumstances as well as of the familiar rhythms of sex and hunger. In this way the organism becomes more subtly tied to its environment—less of a push-button machine reacting only to the immediate change—and the innate restlessness of living matter finds some physiological expression.

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Perhaps the most valuable result of all education is the ability to make yourself do the thing you have to do, when it ought to be done, whether you like it or not; it is the first lesson that ought to be learned; and however early a man's training begins, it is probably the last lesson that he learns thoroughly.—THOMAS HENRY HUXLEY.

Medicinal Uses of Plants by Native Inaguans

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IN the summer of 1954 I spent nearly 2 months on Inagua, southernmost of the Bahamas, which is about 400 mi southeast of Nassau and 65 mi north of Haiti. The island is very irregular in shape, 34 mi long and 25 mi wide, with an area of 560 mi^2 (*1*). The population numbers about 1000, located almost entirely in Matthewtown, the only settlement. There are about 90 white people (men, women, and children) on the island; the rest are Bahamian natives, who are of complex origin. Many years ago, when freighters from northern ports made a practice of calling at the Bahamas to pick up stevedores for unloading cargo in the West Indies and Central and South America, the population was much larger. Nash (*2*) reported that 50 years ago there were twice as many inhabitants as now.

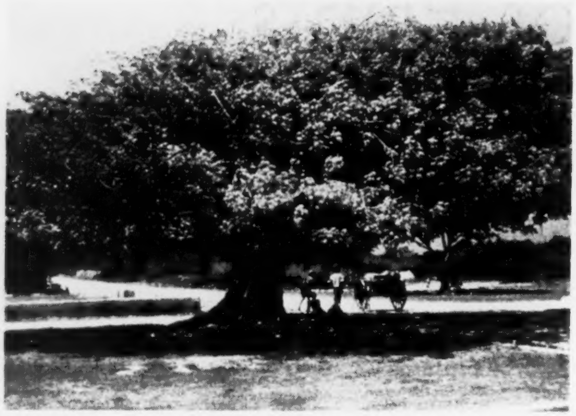
For centuries the manufacture of rock salt has been a major industry on various Bahamian islands. In 1935 the three Erickson brothers took over the then nearly obsolete industry on Inagua. Their West India Chemical Company, Ltd., using modern methods and machinery of their invention, now harvests more than 150,000 tons of salt each year. All the white families are connected with this business, which also furnishes the chief employment for the natives. Other sources of livelihood include small farming, storekeeping, hunting wild cattle and pigs, conching, fishing, and so forth.

Some knowledge of the natives' origin and history is necessary in order to understand their uses of plants. In 1492 Columbus found the Bahamas inhabited by what he called Lucayans, a kindly and indolent race of Arawak Indians, who seem to have been pushed north by the more aggressive Caribs (*3*). Under Spanish domination the Lucayans were removed to Cuba and Hispaniola to work in the mines, where they were exploited and persecuted. After a few decades, none remained in the Bahamas. Today their only trace is in a few skeletons and artifacts that have been found in limestone caves here and there in the islands, and it is doubtful that they have any part in the ancestry of present-day Bahamians.

Near the middle of the 17th century, the first English colonies were established in the northern islands. In the following years, there were frequent conflicts between the English and Spanish, with reprisals and invasions by the latter. Wrecking and piracy became rampant, and it is said that at one time more than 2000 buccaneers made the islands their headquarters. As plantations were developed, the landowners brought slaves from Africa; and after the American Revolution the emigration of Loyalists and their slaves from our southern states more than doubled the Negro population on the northern islands. The English inhabitants were the more stable element in the population, but invasion, wrecking, and piracy added a polyglot mixture of Spanish, Dutch, French, Portuguese, East Indians, and others. Thus the present native population is exceedingly complex, and, although the typical Bahamians are predominantly black, their background includes the ancestry and customs of many races.

Geologists are in general agreement that the Bahamas are of volcanic origin. The igneous foundation, however, is everywhere crowned with coral limestone, often of great depth; it is said that in a recent search for oil on one of the islands, borings 11,000 ft deep encountered only limestone.

Several factors operate to make the Inaguan flora somewhat limited in size and in kinds of plants. Among these factors are (i) the calcareous nature of the substrate; (ii) the sparsity of soil, which rarely reaches a depth of more than 1 or 2 in. except in occasional pockets; (iii) the dryness of the climate, which has an average rainfall of 20 in. limited to about 2 mo of the year; and (iv) the strong and nearly constant trade winds. Much



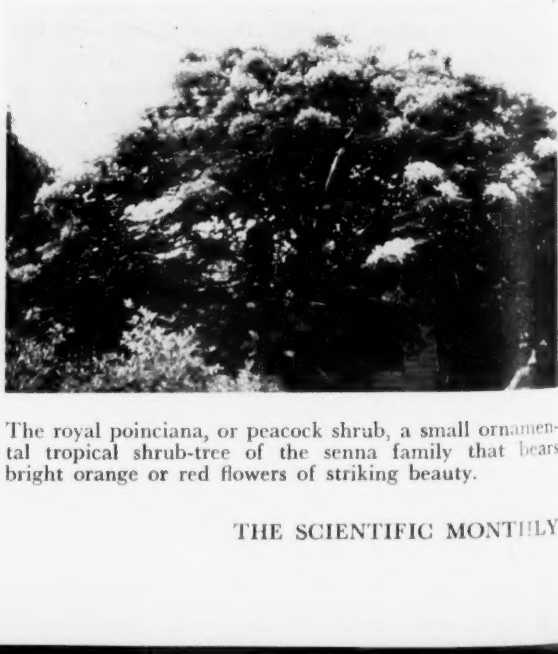
Silk-cotton, or kapok, tree. It often attains a height of more than 100 ft and may bear up to 1000 pods that yield a total of about 10 lb of cottony floss known as kapok floss. Certain natives believe that duppies, or "little folk," live in the huge buttresses of the trees, where they are seen only by the believers.

of the island is clothed with thick, low scrub penetrated only by the paths of wild donkeys. Occasionally open savannas occur, and some areas of bare limestone. There are a few waterholes surrounded by more luxuriant vegetation. The tallest trees are the few coconut palms. There are a few ridges and scattered low hills, but most of the island is only a few feet above sea level. A large, shallow, and brackish lake (Lake Windsor) near the southwest end of the island is the home of one of the largest flamingo colonies in the world.

Considerable taxonomic work has been done for the Bahamas. As one would expect, however, this work has centered mainly around New Providence and the adjacent northern islands. Inagua, most remote of the "out islands," has received relatively little attention. The most extensive study was made by Nash and Taylor (*4*) in 1904. They made a collection of 482 species, which was deposited in the herbarium of the New York Botanical Garden. *The Bahama Flora* by Britton and Millspaugh (*5*), published in 1920, is the most comprehensive and, apparently, the most recent survey of all Bahamian plants. This work and the section on plants in *The Bahama Islands,* by the Geographical Society of Baltimore (*6*), served as the main sources for identification of the plants in Table 1. The fact that my cursory examination of the island flora has disclosed a number of species not listed in either of these publications points to the need for more work on Inagua (*7*).

It is only within the last few years, since the development of the present salt industry, that a physician or nurse has been living on this remote island. For a long time, therefore, the natives have had to be self-dependent for treatment of their ailments. Their medicinal uses of plants are based on a tangle of fact, fancy, and folklore. Much of their information has been handed down from generation to generation and, in some cases, no doubt goes back to African or other forebears. Now that modern medicine has come to the island, it is likely that this ancient lore will soon be lost. That it may in part be preserved is one of the incentives for this study.

I have cross-checked the common names and uses of the plants listed in Table 1 with several of the older residents and have listed only those on which there was agreement by all concerned. The botanical names used are those given by Britton and Millspaugh (*5*). Whenever possible, the plants and their medicinal properties have been checked in the *United States Dispensatory* (*8*) and *Webster's New International Dictionary* (*9*). These works, as might be expected, have confirmed the natives' uses in some cases but in others have failed to mention the plant concerned or have listed its medicinal properties as obsolete. In two instances it is suggested that the native use may be harmful or even dangerous. Thus *Vernonia,* according to the *United States Dispensatory,* "contains a principle Vernonin, which is a cardiac poison of the digitalis group"; and although the leaves of the Sea-island cotton are not mentioned, the root is listed "by Bouchelle in 1840 as a popular abortifacient among Negro slaves." Whenever the *United States Dispensatory* or *Webster's Dictionary* mentions one of the plants listed in Table 1, its comment has been added for comparison.



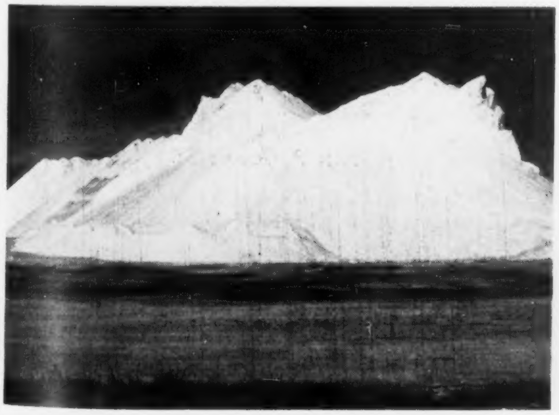
The royal poinciana, or peacock shrub, a small ornamental tropical shrub-tree of the senna family that bears bright orange or red flowers of striking beauty.

Table 1. Medicinal uses of plants by Inaguans. The comments *U.S. Disp.* were obtained from the *Dispensatory of the United States* (*8*); *Webster* from *Webster's New International Dictionary* (*9*).

Common name of plant	Latin name of plant	Preparation and dose	Comment
		Coughs and colds	
Moringa (horse-radish tree)	*Moringa moringa* L. (*M. pterygosperma* Gaertn.; *M. oleifera* Lam.)	Boil flowers 15 min; add lime juice. Sip liquid at frequent intervals	*U.S. Disp.*: bark of *M. oleifera* yields two alkaloids similar to ephedrine in physiological action. *Webster*: source of oil of behen
Bay tansy (sweet bay; bay geranium)	*Ambrosia hispida* Persh.	Beat and strain leaves; add salt. Drink liquid	*U.S. Disp.*: formerly used by eclectics for medicinal purposes
Gale-of-wind	*Phyllanthus niruri* L.	Boil leaves; add lime juice. Drink liquid	*U.S. Disp.*: roots of *P. niruri* are used in South America for medicinal purposes. The leaves contain a neutral bitter principle used as a fish poison
Sourbush (coughbush; wild tobacco)	*Pluchea odorata* L.	Steep leaves. Sip liquid	
Swordbush (rockweed)	*Xylophylla epiphyllanthus* (L) Britton	Chew leaves. Swallow juice	
		Fevers	
Tamarind	*Tamarindus indica* L.	Boil leaves 20 min; add lime juice and sugar. Drink liquid	*U.S. Disp.*: used as mild cooling laxative drink for febrile conditions. *Webster*: fruit used in pharmacy as a source of a cooling laxative drink
Bay tansy	*Ambrosia hispida* Persh.	Beat and strain leaves; add salt. Drink liquid	
Sweetwood (cascarilla)	*Croton eluteria* L.	Steep bark. Sip decoction	*U.S. Disp.*: although once used as a subsitute for cinchona, it probably has no other therapeutic value than that of a bitter aromatic stomachic. *Webster*: used in pharmacy as a tonic and stomachic
Love vine	*Cuscuta americana* L.	Boil plant. Drink liquid	
		Eye inflammation	
Tamarind	*Tamarindus indica* L.	Soak leaves overnight in cold water in open air. Bathe eyes with water	
		Fish poisoning	
Blackwood	*Picrodendron macrocarpum* (A. Rich.) Britton	Make tea from leaves. Drink tea	
		Toothache and mouth sores	
Bay cedar (tassel plant)	*Suriana maritima* L.	Boil roots or twigs; add handful of salt and steep. Inhale vapor or hold liquid in mouth	
		Tuberculosis	
Bay tansy	*Ambrosia hispida* Persh.	Steep leaves. Drink liquid	

Common name of plant	Latin name of plant	Preparation and dose	Comment
		Intestinal parasites	
Blue-flower vine. (Jamaica vervain)	*Valerianoides jamaicensis* L. (*Stachytarpheta jamaicensis* Vahl.)	Beat leaves; add 10 drops of juice to 1 tsp of sugar. Take on empty stomach	*U.S. Disp.*: vervain contains a principle that has a weak stimulating effect on the parasympathetic nerves. Formerly used by the laity as a sudorific
Vermifuge	*Eupatorium bahamense* Northrup	Beat and strain leaves; add pinch of salt. Starting on new moon, 1 tsp each morning for 9 days	*U.S. Disp.*: *E. perfoliatum* used as an emetic and aperient. *Webster*: eupatorin, prepared from *E. perfoliatum,* used as an expectorant
Wormseed (Jerusalem oak)	*Chenopodium ambrosioides* L.	Beat leaves and strain through cloth. Take 1 tsp juice each day for 9 days and castor oil on 10th day	*U.S. Disp.*: no question as to the activity of wormseed as "an anti-helminthetic
		Sores and boils	
Wild ginger	Orchid sp.	Beat up bulb. Use as poultice	
Sorebush (Scorpion's-tail)	*Heliotropium parviflorum* L.	Boil leaves or crumble leaves to powder. Wash sores with liquid or dust with powder	
Daddy-Joe	*Abutilon permolle* (Willd) Sweet	Boil leaves. Bathe sores with decoction	
		Pregnancy	
Sea-island cotton	*Gossypium barbadense* L.	Boil leaves. Drink decoction for nausea	*U.S. Disp.*: no mention of leaves, but cotton root bark cited as abortifacient among Negro slaves; causes vasoconstriction and contraction of uterine muscles. It also has a slight narcotic action
		Backache	
Horsebush	*Gundlachia corymbosa* (Urban) Britton	Beat leaves; steep in water. Drink liquid; bind hot leaves on back	
Four man's strength	*Lantana camara* L.	Boil leaves and twigs. Drink decoction	*U.S. Disp.*: *L. camara* and *L. braziliensis* contain an active antipyretic
Strongback	*Bourreria ovata* Miers	Brew leaves. Drink liquid	*Webster*: strongback is a variation of strongbark, *B. ovata,* and is used as a beverage in the Bahamas
		Astringent	
Grannybush (Bay wormwood)	*Croton linearis* Jacq.	Brew leaves. Use after childbirth	
		Jaundice	
White sage	*Vernonia bahamensis* Gris.	Boil leaves. Drink tea	*U.S. Disp.*: *V. nigritiana* root used in Senegal as a febrifuge, emetic, and antidysenteric. Somewhat resembles ipicac in therapeutic action. Vernonin is a cardiac poison of the digitalis group

Common name of plant	Latin name of plant	Preparation and dose	Comment
		Colic	
Pipe-Shank (lion's-tail)	*Leonurus sibiricus* L.	Boil leaves. Drink liquid, and apply leaves to stomach as a compress	
		Tonics	
Wild ginger Cascarilla Gum elemi Moujean tea Brasilletto	Orchid sp. *Croton eluteria* *Elaphrium simarubra* L. *Nashia inaguensis* Millsp. *Caesalpinia bahamensis* Lam.	All are made into teas. Used as appetizers, tonics, or for refreshment	*U.S. Disp.*: cascarilla is a stomachic; gum elemi has properties similar to turpentine; brasilleto formerly used in medicine
		Diarrhoea	
Swordbush	*Xylophylla epiphyllanthus* (L) Britton	Stew leaves. Drink decoction	
Blind-eye bush (cowbush)	*Helicteres jamaicensis* Jacq.	Make tea from leaves. Drink tea	
		Stomachache	
Doctor's club (heartless club)	*Zanthoxylum coriaceum* A. Rich.	Steep leaves in gin Drink decoction	
		Malaria	
Princewood	*Exostema caribaeum* (Jacq.) R. & S.	Steep bark. Drink decoction	*Webster*: princewood bark affords bitters
		Purgative and antihelminthetic	
Bitter aloes	*Aloe vera* L.	Collect juice. Take few drops on sugar	*U.S. Disp.*: bitter aloes is used as a laxative
		Measles	
Red sage	*Lantana bahamensis* Britton	Make decoction of leaves. After 3 days of symptoms drink the hot liquid to bring out rash. Bathe patient in similar liquid	*U.S. Disp.*: *L. bahamensis* and *L. camara* contain an antipyretic



A salt pile at Town Pans, Inagua, Bahama Islands. The manufacture of rock salt is a major industry.

Salt pans. Water collects in these depressions and leaves a deposit of salt after it evaporates.

Common name of plant	Latin name of plant	Preparation and dose	Comment
		Proud flesh	
Sea-island cotton	*Gossypium barbadense* L.	Crush leaves. Squeeze juice on inflamed area	
		Rheumatism	
Lignum vitae	*Guaiacum sanctum* L.	Boil bark. Rub hot decoction on afflicted area	*U.S. Disp.*: formerly used for skin diseases, scrofula, and syphilis. Now restricted to use for rheumatism

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The Mountains and the Desert

Like ghosts of thoughts upon the margins of the mind
The purple mountains fade along the desert's dusty rim.
Here in this shimmering heat of doubt one cannot find
Significance in shapes so far away, in forms so dim.

One foot behind the other,
One mile beyond the next,
This hour, perhaps another
Are the compass of the text.

The formless Here is All—for faces in the dust.
But some have luck to gain once more the heights that probe the sky
And sense in those uplifted fingers, as they must,
The frame that undergirds the arid flats where deserts lie.

JOHN P. GILLIN

BOOK REVIEWS

Science Awakening. B. L. Van der Waerden. Trans. by Arnold Dresden. Noordhoff, Groningen, Holland, 1954. 306 pp. Illus. + plates. $5.

THIS well-written, beautifully printed, handsomely illustrated book will prove of great value to any one who is interested in the historical aspects of mathematics. The title should not mislead the reader into believing that Van der Waerden has included any material on "science," even "exact science" which might include astronomy and parts of physics such as optics. In this limited domain Van der Waerden has produced a work of exceptional merit, which is likely to remain the standard book in early mathematics for some time to come.

One of the most attractive features of this book is the wealth of factual material it contains. Major texts are quoted as well as analyzed, so that the reader may follow the stages of interpretation with the control of the original material. This is especially important in the case of much of early mathematics because the texts themselves are often vague or fragmentary and can, therefore, easily give rise to conflicting interpretations.

Another valuable feature is the care with which Van der Waerden always distinguishes between verified fact and opinion. A classic error, widely accepted by uncritical writers, is that the ancient Egyptians knew the 3-4-5 triangle. The only basis for this statement is the known fact that "rope-stretchers" were employed in laying out an Egyptian temple, the fact that such temples have fairly accurate right angles, and the fact that a rope with 12 equal lengths marked on it can be stretched into a right triangle. But there is no evidence whatsoever that the Egyptians knew this property of right triangles and there is at least one other way of stretching ropes so as to make a right triangle. Van der Waerden rightly scorns the so-called "historical" method that results in such grossly mistaken conclusions.

For most readers the opening chapters, dealing with the Egyptians and the Babylonians and number systems, digits, and computing will prove the most valuable. I believe that this section of the book is easily the best factual survey of pre-Greek mathematics available in the English language. Making effective use of the magnificent research of Thureau-Dangin, Neugebauer, and Sachs, Van der Waerden has been able to present the extraordinary mathematical achievements of Mesopotamia that have become known only in recent decades. Much as we may admire Greek mathematics, there is no longer any excuse to write of its development as "the Greek miracle."

The panorama of ancient mathematics as it developed from the early Near East to the "golden age" of Greece and its eventual decline in Alexandria is presented by Van der Waerden in terms that anyone who has studied secondary-school algebra and geometry can comprehend. The author is a distinguished mathematician, especially well known for his work in modern algebra, who displays here and in his other recent historical writings a keen perceptive sensitivity for the development of mathematical thought. The translation is excellent, done by the late Arnold Dresden, a beloved figure in American mathematics. The wealth of information contained in this book, so admirably presented, should provide a corrective to many misinterpretations now current and should attract a host of readers who will share with the author the fascination of the growth of exact thought.

I. BERNARD COHEN
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Galen of Pergamon. George Sarton. Univ. of Kansas Press, Lawrence, 1954. 112 pp. Illus. $2.50.

THIS book grew out of the third series of Logan Clendening lectures on the history and philosophy of medicine, delivered at the University of Kansas in memory of a well-known physician, historian of medicine, and bibliophile. Sarton's aim was not to break new ground for specialists but to evoke the figure of Galen for a general audience. There is certainly no other short book in English as well adapted to this purpose.

The author pays warm tribute to Galen's experimental researches, including his proof (against Erasistratus) that the arteries carried not air but blood and his discovery that monkeys became paralyzed below the level at which their spinal cords were cut. Yet, for better or worse, Galen not only made experiments but philosophized and built theories.

In his capacity of medical philosopher he arouses mistrust and even exasperation in Sarton. Everyone would agree that there is much occasion for this, but in my opinion Sarton has overstated the case. The two main counts in his indictment of Galen are too much teleology and not enough empiricism. Without running to the opposite extreme, one would say of the first point that Galen's teleology often served in his own writings as a stimulus to the correlation of structure with function, and that even today many biological scientists practice a kind of "as-if" teleology. As for the second point, one may readily concede that Galen did not have a sufficient empirical basis for many of the structures of thought that he built. But here Sarton's position is weakened by the clear implication that there was a preferable alternative to Galen's general attitude, namely that of the so-called "empiricists." Now the point about the empiricists is that they ended by despairing altogether of the possibility of building a medical science and talked as if every individual case of sickness would have to be treated absolutely *de novo*. They turned the old Hippocratic aphorism inside out

and said in effect that life was long and the art ephemeral. There can be no serious doubt that not the empiricists but Galen, by calling for a union of theory and observation in medicine, had taken up the only truly scientific position. Whether in *practice* he always mixed the two ingredients in their proper proportions is another matter.

Apart from his role in the history of medicine, Galen belonged to the age in which classical culture was first confronted by Judaism and Christianity. Sarton, with the ethical and humane current that runs through all his writing, naturally gives some account of Galen's attitude toward the two faiths. Unfortunately, this section of the book appears to be inadequate in the light of recent work by the celebrated Arabist Richard Walzer. Walzer argues that Galen knew a body of educated Christians in Rome, challenged them to make their doctrines rational and intelligible by the standards of Greek philosophy, and in general led them on into a "hellenizing" of Christianity which got them castigated as heretics. Not all the steps of this argument are equally secure, but if there is any substance at all to Walzer's claims, Sarton has seriously underestimated the significance of Galen's contact with the Christians of Rome.

A valuable feature of this book which ought not to go without mention is the listing in an appendix of the comparatively meager body of Galenic texts that have been translated into English.

Donald Fleming
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Béla Schick and the World of Children. Antoni Gronowicz. Abelard-Schuman, New York, 1954. 216 pp. Plates. $3.75.

ANTONI GRONOWICZ's biography of Béla Schick is an absorbing description of the life and achievements of one of the truly great men of our times. The preface is written by Rene J. Dubos of the Rockefeller Institute for Medical Research.

The early chapters afford an insight into Schick's family background, his early school days in Graz and his medical training there, and later in Vienna. Schick's rise to international fame and the adverse circumstances, economical and otherwise, under which he at times labored are vividly described as well as his close association with other great personalities in science. Among the renowned personalities reflected in his career are Friedrick Kraus, Theodor Escherich, and Schick's close friend and collaborator, Clemens von Pirquet.

Later chapters are concerned with Schick's medical career in this country, to which he came in 1923 as chief of the department of pediatrics, Mt. Sinai Hospital, New York. Here he continued to enrich medical knowledge and practice.

The work concludes with an epilogue by Edwards Park and a listing of Schick's many published articles concerned with a wide variety of medical subjects. The majority of these are written in German.

Throughout the book ample evidence is afforded of Schick's broad interest in medicine. His investigative efforts seemed always directed towards a practical application for the betterment of humanity. It is only natural that special emphasis is given to the Schick skin test detecting susceptibility to diphtheria, and to the fundamental knowledge of allergy described 50 years ago by Schick and von Pirquet, which constitutes the basic principles of the present practice of allergy.

When one reads Gronowicz's account of this great man and his accomplishments, one is impressed by Schick's singular dedication to his chosen profession, his great humility, and his apparent disinterest in the economic aspects of the practice of medicine. The book and the European setting of the early chapters afford a good glimpse of medical progress in the past 50 years and well deserves a place in any physician's library.

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American Thought. A critical sketch. Morris R. Cohen. Free Press, Glencoe, Ill., 1954. 360 pp. $5.

IN 1947 Morris R. Cohen died without completing the book on contemporary American thought that he had begun more than a score of years before. His long and tireless search for the verities postponed the fruition of his plans, and to his son and literary executor, Felix S. Cohen, fell the task of putting the mass of material into book form. Felix Cohen said that the passing years emphasized some of the gaps in the volume

> . . . but they have not detracted, I think, from the significance of the reflections here assembled. For what is most significant of these reflections is that they are the product of a single pioneer mind that has ranged widely on the frontiers of American reflective thought and brought to many diverse fields a unified and unifying perspective. And in a world where academic compartments and other barriers to the free interchange of ideas threaten to make philosophy itself a specialized discipline, there is greater need than ever before for consistent perspectives that range over the broadest horizons of the human mind.

There would be few dissents from this evaluation, whatever the conditions that produce a greater need for them now than in other periods.

It is a fortunate circumstance, indeed, that Felix Cohen was able to assemble this legacy from essays and lecture notes, omitting all the chapters begun but not completed. Felix Cohen died before the manuscript was in page proof, and the final work of editing was done by his wife, Lucy Kramer Cohen. The loving care that his son and daughter-in-law gave to the task have made the volume a welcome addition to the other writings that came from the mind and heart of Morris Cohen.

In order to arrive at a better appreciation of the author's viewpoint, it is necessary to be familiar with

his autobiography, *A Dreamer's Journey,* also completed by his son and published in 1949, 2 years after his death. Perhaps Morris Cohen's greatest influence was exerted as a teacher for 36 years at the City College of New York. Many hundreds of his pupils took their places in the life of America enriched by their experience with him, enthusiastic lovers of knowledge and wisdom. He has been described as

> . . . one of the most searching critics of empiricism, instrumentalism, nominalism, and all other forms of philosophic thought that failed to uphold the independent, integrative function of Reason.

His refusal to conform and to bend the knee to generally accepted doctrines, procedures, patterns, and beliefs have helped, as others have pointed out, to throw the trend of philosophic thought in America into a much needed perspective. But he has done much more than this. In some fields he has helped to bring about changes that have had an important bearing on the conduct of American affairs.

His special interests, as he said himself, were in the fields of jurisprudence and scientific method. And he pointed out that the courts were not organized to make use of scientific methods and of scientific evidence. Judge Margold wrote in *Freedom and Reason* (1951) that what Morris Cohen had to say as far back as 1913 in his paper on "The process of judicial legislation" served to "supply the text to which the most valuable work of progressive jurists since that time has been commentary." The text, as Morris Cohen repeated again and again, was that courts make law. And to show, as Morris Cohen did,

> . . . that they did find the premises for the law they make not only within, but also outside of, the law books, is to show the need for scientific canons in incorporating economic, political, and other social data into the legal process.

So what Morris Cohen described as the "phonograph theory of justice" lost its grip on the bench and bar and is fast becoming obsolete, even in the law schools. Today the administrative and investigative side of the judicial process is being expanded, there is increasing recognition of the role of social outlook, and, in the words of Margold, it was the vitality of the philosophy used by Morris Cohen to break down the walls that separated law from the social sciences. "The trumpets still echo and the walls go crumbling down."

In a discussion with F. S. C. Northrop, of Yale University, Morris Cohen said: "One must believe in absolute knowledge and at the same time not believe in it." This is interpreted by Northrop to mean that scientific knowledge is absolute with respect to its meaning but not absolute with respect to the certainty of its verification. Whatever his ideas on the absolute and nonabsolute in scientific knowledge, Morris Cohen, in his chapter on scientific thought, says:

> Philosophy is often an apology for the opinions or attitudes that philosophers have held. Science makes no apologies. It subjects all views to the same objective tests. Whether truth has any value is a question that is irrelevant to the scientist's task. . . . At any rate, the activity of science considered merely as play, the search for truth, is a liberating activity and makes life worthwhile apart from any utilitarian values that the discovery of truth may serve. Liberalism and the method of science are closely interwoven. Liberalism paves the way for science by removing obstacles to the development of human energy. Science, in turn, affords greater opportunity for the liberation of human energy.

The volume contains nine chapters: "The background of the American tradition," "American ideas on history," "Scientific thought," "Economic thought," "Political thought," "Legal thought," "Religious thought," "Aesthetics," and "General philosophy." The greater part of the book is devoted to the chapters on legal thought and general philosophy, and those chapters contain more specific discussion of the scholars and writers in relevant fields. It is to be regretted that other chapters on which Morris Cohen had prepared himself over the years were not completed before his death, but there is enough to give an understanding of the basis for his position among the foremost scholars on the American scene. He was disturbed over conditions that seemed to be destroying the usefulness of the philosophy he loved so much. "The older ideas of philosophy as a kind of universal knowledge or a way of life have fallen into desuetude." Whether or not one agrees with all his evaluations of ideas and with his sometimes gloomy perspectives, this book is an extremely important history and exposition of American thought and fully merits its billing as a unique achievement.

PHILIP B. PERLMAN

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Psychotherapy and Personality Change. Co-ordinated research studies in the client-centered approach. Carl R. Rogers and Rosalind F. Dymond, Eds. Univ. of Chicago Press, Chicago, 1954. x + 447 pp. $6.

RESEARCH designed by the Counseling Center Staff of the University of Chicago to test the effectiveness of client-centered psychotherapy is reported here. In this program two groups of subjects were used: (i) an experimental group of 29 clients, one-half of whom were asked to wait 60 days before beginning therapy and one-half of whom were started immediately on application; (ii) a control group not seeking therapy. Tests were given at the time of applying (for the waiting group), at the beginning of therapy, at the end of therapy, and after a 6- to 12-month follow-up period. The control group was tested at comparable time periods.

In brief, the findings are that clients do change with psychotherapy and that the changes cannot be ascribed either to the interval of time between tests or to practice in taking tests. Examples of change are (i) movement of client self-view toward what he would like to be; (ii) increased self-understanding, comfort, optimism, and the like; (iii) increased in-

tegration as shown by the thematic apperception test; and (iv) increased maturity of behavior as judged by friends in those cases where progress was shown by the other measures. Greatest improvement was shown where counselor attitude toward clients was warm, respectful, and nondemanding.

This book represents the first systematic work on the outcome of psychotherapy in which controls are instituted so that the results may be interpreted meaningfully. Many workers will have doubts about how far these findings can be generalized, because the number of cases is so small and the orientation is so circumscribed. This work should, however, serve as a challenge to investigators of other orientations to do comparative research.

A more serious question perhaps is the almost exclusive reliance on phenomenological data in the study. The phenomenological theory that has grown with the client-centered approach apparently does not stimulate its adherents to do research in other aspects of personality. It is significant that the only study in the book that deals with client behavior as opposed to client feeling relies for its data on judgments by untrained people—friends of the clients. Behavior within the interviews is put aside, for the present at least, as a source of research material. The "process" of psychotherapy is studied, not by examining what goes on between client and counselor in the interviews, but by tabulating counselor attitudes toward clients. Some remarks in the closing chapter indicate a feeling on Rogers' part that there is an "either-or" situation between phenomenological research and other sorts of research. Many psychologists say that although the inner life of the individual is important, it is not the only important part, and that research on the relationships among all the various aspects of the individual will yield more fruitful results than research on any one aspect alone.

ALLEN T. DITTMAN
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Pajarito Plateau and Its Ancient People. Edgar L. Hewett. Rev. by Bertha P. Dutton. Univ. of New Mexico Press, Albuquerque, ed. 2, 1953. x + 174 pp. Illus. + plates. $4.50.

ACROSS the Rio Grande Valley from Santa Fe, below the rounded volcanic Jemez Mountains that form the western skyline, lies an area of unusual archeologic and natural interest—the forest-clad mesas and canyons of the Pajarito Plateau. This foothill area is formed largely of tuff, water-laid fine volcanic ash, a quite soft rock plus lava and gravel. In many of the cliffs, artificial cave rooms were excavated long ago by pre-Spanish Indians working with tools of harder stone. These distinctive structures contrast with other Southwestern "cliff-dwellings" built in under natural shelters. There are also many other less unusual pueblo ruins that date largely from late pre-Spanish times and into the historic period—from the 13th to the 16th century. Descendants of the builders still live along the Rio Grande.

In a delightfully written popular book, first published in 1938, the late Edgar L. Hewett describes the setting, the archeologic sites, and the findings of his excavations 30 years earlier in Bandelier National Monument (Frijoles Canyon, Tsankawi, and Otowi), the Puye ruins (on the Santa Clara Indian Reservation), and other sites. The general discussion of Pajarito Plateau archeology includes a short section on "The cave pictographs of the Rito de los Frijoles," by Kenneth M. Chapman.

Fifteen years after the original publication and several years after Hewett's death, one of his students and assistants, Bertha Dutton has done a competent job of revision. She has preserved the spirit and continuity of Hewett's work, and at the same time she has inserted considerable material on later finds and newer concepts, with specific data on ceramics and specific dates from tree-ring studies, and has added a final section on the contemporary Pajaritans of Los Alamos.

ERIK K. REED
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Thoreau: a Century of Criticism. Walter Harding, Ed. Southern Methodist Univ. Press, Dallas, Texas, 1954. x + 205 pp. $3.75.

HOW does one best study the works of a word artist? Should one plunge in, as a swimmer does who fears the water may be cold and wishes the shock to be short? Or should the approach be made with more formality through a letter of introduction from a mutual friend? For those who elect the latter plan, this book may well serve as that "letter of introduction."

Here under one cover are representative estimates of Henry David Thoreau and his work that have been made over a period of 102 years. Preachers, poets, artists, novelists, psychologists, naturalists, and scientists say that they find in him and his records much that merits attention. A partial catalog of their names includes Emerson, Lowell, Robert Louis Stevenson, Burroughs, Sinclair Lewis, Havelock Ellis, and Bronson Alcott.

Although the editor has exercised choice he has not skewed the picture by deleting estimates of "those who have damned" Thoreau, and so the book is not biased toward undue laudation. In 24 essays, fairly distributed over the century, one finds evidence of a growing appreciation for the life and thought of Thoreau. Each excerpt is prefaced by a "few background comments" by the editor. These comments, a chapter as "Introduction," and a creditably explicit table of contents are the reader props.

Editor Walter Harding is considered "one of America's leading specialists on Thoreau," and he has "the largest private library of Thoreau in existence." This volume has evolved out of his 13 years of secretarial and editorial service for the Thoreau Society.

B. CLIFFORD HENDRICKS
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The Microphysical World. William Wilson. Philosophical Library, New York, 1954. vii + 216 pp. Illus. $3.75.

THIS small book deals with the very small things in the physical world! After an introductory description of the large-scale world as viewed by the astronomer, the author goes directly to the atomic theory of Dalton. A historical approach is used throughout in describing such topics as spectra, cathode rays, x-rays, radiant heat, hydrogen and helium atoms, and both the orbital and nuclear structures of atoms. Quantum theory and wave mechanics are discussed. Many of the milestones in the development of our modern, fundamental concepts of the structure of matter are described.

The Microphysical World is directed to "the intelligent layman," not to the scientist or student of science. Wilson has attempted to do this without sacrificing accuracy and with scientific terminology. Many topics are described as if for the beginner, but others are brought in and used without consistently adequate explanation. In several instances, discussion of a particular topic is ended abruptly and application and conclusion must be found in subsequent chapters.

The book is written in a first-person, conversational style. Some sentences are so long and so complex in structure that the meanings are not clear upon first reading. A layman, even an intelligent one, would likely have to proceed very slowly through this book; even then he would likely not comprehend all that he reads.

ROBERT B. FISCHER
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Sex and Morality. Abram Kardiner. Bobbs-Merrill, New York, 1954. 266 pp. $3.

IN *Sex and Morality* we have a readable exposition of Abram Kardiner's theories and views as he seeks to explain some of the phenomena of the current Western culture, particularly those pertaining to the sexual area. Since the cover recommends the book to "every thoughtful American"—that is, a lay audience for the most part—it has the defect found frequently in psychiatric writing: it does not clearly distinguish between what are the author's personal opinions and what data are backed up by some scientific work. A case in point is Kardiner's statement that juvenile delinquency, schizophrenia, and homosexuality have shown a more frequent incidence in the recent past. These assumptions then are utilized as jumping off points for theory building; for example, the discussion of "The flight from masculinity," as Kardiner postulates such a situation, relates to homosexuality and several other factors. Although some case may be made for an absolute increase in the incidence of juvenile delinquency, no such case can be made for schizophrenia and homosexuality. Hence I am doubtful of the theories, although they do represent interesting assumptions and points for discussion among "thoughtful Americans."

Kardiner quite properly laments that the American public may have become confused in past years by the plethora of published theorizing in psychological matters, particularly with respect to how one should rear his children. Kardiner to some degree falls into the trap he laments, and this volume if read in serious earnest by a psychologically unsophisticated, albeit thoughtful, male would be less than reassuring.

In spite of these defects the book is worth reading. It points out some apparent shifts in our mores and is thought-provoking.

The author has an enviable ability to put his thoughts to paper in an easy style, and there is no use of technical language to confound the reader.

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Biological Applications of Freezing and Drying. R. J. C. Harris, Ed. Academic Press, New York, 1954. xii + 415 pp. Illus. $10.

ACCORDING to the editor, this volume is intended to provide a comprehensive and authoritative treatise on freezing and freeze-drying and to serve as a reference work or guide for all those using or wishing to use such techniques. If the book falls short of such an ambitious objective, the editor cannot be blamed entirely, for it is difficult to bring together the many diverse subjects that are related only through use of certain common technical procedures.

For descriptive purposes, the contents may be divided into three parts. One group of chapters is related to each of the two principal types of freeze-drying and the third is a miscellaneous group related somewhat to the problem as a whole. The first group (chaps. 4–8) covers the development and commercial application of methods for the freeze-drying preservation of blood plasma, antibiotics, mother's milk, foodstuffs, and culture media. These labile bulk materials must be preserved with so little chemical alteration that they may be reconstituted and used in place of the original starting material. These chapters vary greatly in style, length, and interest, but as a group serve to show major uses to which freeze-drying has been put and how these applications came about.

A second group (chaps. 9–11, 13, 14) deals with the freeze-drying preservation of the precise structure and the physiological and biochemical attributes of living materials. Chapters on preservation of viruses, bacteria, and living tissues, and on the use of freeze-drying in electron microscopy and for morphologic and histochemical studies are well written and comprehensive. These will probably be the meat of the book for the laboratory scientist.

The remaining chapters (1–3, 12) constitute the miscellaneous group that might have been expected to provide integration and continuity for the whole. These cover the effects of low temperatures on living cells and tissues, the development of freeze-drying, theoretical aspects of drying by vacuum sublimation, and the effect of residual moisture in frozen-dried material and its

measurement. The first of these, on the effects of low temperatures on living cells and tissues, is of considerable theoretical interest. It is accompanied by a valuable and extensive bibliography, which includes references to a great many early papers as well as recent publications. Unfortunately, the attempt to include so much in this chapter has resulted in a somewhat uncritical presentation and a compressed encyclopedic style.

The chapter on the development of freeze-drying concentrates and the practical applications of the process to the preservation of bulk biological substances all but omits the use in tissue preservation for histologic purposes—although this application is much the older and is to be credited with the revival of Altmann's technique in the early thirties.

Much of the text re-covers the ground of other rather recent books and reviews; yet the book will probably find a place with workers who will apply freeze-drying techniques to new problems. For both the serious student of the technique and for the scientist who employs freeze-drying occasionally, it is to be commended as a source for references to the widely scattered literature.

Technically it has received excellent treatment. Typography, printing, and binding are good; illustrations are clearly reproduced and adequate in number.

WILLIAM L. SIMPSON
Detroit Institute of Cancer Research

Wildcat Strike. Alvin W. Gouldner. Antioch Press, Yellow Springs, Ohio, 1954. 179 pp. Illus. $3.

THIS is an investigation of a specific wildcat strike in a gypsum plant. It concludes with two chapters on "Rudiments of a general theory of group tensions" and "Threats, defenses and organizational character." The investigation seems to have been both thorough and acute, and the results should be useful to everyone interested in industrial relations.

Sociologists will probably get the most out of the book, because they, presumably, will understand the language in which it is written. Unions, management, and the general public will first have to translate it into plain English. This is a pity, because what Gouldner has to say (as far as I can make it out) seems to me important to people on both sides of the bargaining table and to citizens generally. But he spoils it by wearisome repetition, unintelligible jargon, and frequent use of words in senses that bear no relationship to their dictionary meanings. In one case (p. 23), having taken nearly three lines to say something elaborately and unintelligibly, he provides a brief English translation himself: "Knowing what the workers like, it is possible to predict what they will dislike." But, evidently horrified by this lapse from stern academic virtue, he hastens to retranslate into four lines of jargon, beginning, with unconscious irony, "Knowing, in short."

Struggle is good for the soul, but this book really carries the thing too far.

EUGENE FORSEY
Canadian Congress of Labour

Coro-Coro. The world of the scarlet ibis. Paul A. Zahl. Bobbs-Merrill, Indianapolis, Ind., 1954. xv + 264 pp. Plates. $4.50.

FOR sheer brilliance perhaps no other bird can rival the scarlet ibis—flaming red from head to tail with jet-black wing tips. A denizen of the endless mud flats of the coast of northern South America and the low-lying marshes to the interior, the scarlet ibis may once have occurred as a straggler north to the Gulf Coast of the United States. Audubon himself had a glimpse of three flying over the Bayou Sara in Louisiana. It is rarer now—the colorful plumes have been in demand for tying trout flies—and is to be seen only by those who visit the malarial swamps of northern South America.

To make matters more difficult the Coro-coro, as the natives call this wader, nests during the rainy season. But Paul Zahl, whose superb photographs of *Scolopax rubra,* to use the name Linnaeus gave this bird, first appeared in the *National Geographic Magazine,* possessed the fortitude to enter the Venezuelan marshes during the time of floods.

A laboratory scientist, Zahl is a student of the biology of cancer, and his photographic voyages in quest of scarlet ibis, flamingos, and ocean life are interludes from an indoor routine. The present book understandably contains digressions on a great variety of biological topics. Laymen will find here an informal presentation of much recent theory. Meanwhile, the search for the ibis goes on through the endless labyrinths of the tributaries of the Orinoco and at length all is crowned with success. Even so, there is a final adventure as the author is dangerously lost in the marshes, when he sets out for home with an old man of failing eyesight as guide.

DEAN AMADON
Department of Birds,
American Museum of Natural History

Introduction to Atomic and Nuclear Physics. Henry Semat. Rinehart, New York, ed. 3, 1954. xii + 561 pp. Illus. $6.50.

THE principal feature of this new edition of a well-known textbook is an extended and up-to-date treatment of nuclear processes, fission, isotopes, fundamental particles, and particle accelerators. The material of the first two sections, "Foundations of atomic and nuclear physics" and "The extranuclear structure of the atom," remains substantially the same, except for subdivision of the chapters and some rearrangement of topics to conform to the new section on nuclear physics at the end. Some of the new topics, now included in the earlier sections, that modernize the treatment and serve as teaching aids include a description of the mks system of units, wave and group velocities, phototubes and scintillation counters, diffraction of neutrons, the Auger effect, and Cerenkov radiation. The excellent introduction to optical spectra and the vector model of the atom remains, with new material on

nuclear magnetic moments and resonance phenomena included. Diagrams and photographs have been improved, important equations are now "boxed," problem lists have been revised and extended, and new references are included at the ends of the chapters. Page by page the new edition creates the impression of a good book made better.

W. PAUL GILBERT

Department of Physics, Lawrence College

Atomic Science, Bombs and Power. David Dietz. Dodd, Mead, New York, 1954. xv + 316 pp. Illus. + plates. $4.50.

THERE are some books on special topics that a specialist ought not to review. David Dietz, science editor of the Scripps-Howard newspapers, has produced such a book. The work is a brief account of a bewilderingly wide field, including a "historical survey of atomic theory from the time of the Greeks," the story of 20th-century atomic physics, the tale of the Manhattan Project, through Hiroshima and Nagasaki, postwar developments, and the struggle for international control. The index indicates the scope very well. I cite five consecutive entries taken at random: Pair production, Panamint (ship), Paracelsus, Parsons, William S., Paschen series. . . . If names make news, Dietz has done a really newsy volume.

Not many errors appear to mar the work, either. The author comes a cropper only in his efforts to make clear the nature of the chemical forces, which he certainly fails to understand. But the whole account of the elements and their meaning, from Thales to Otto Hahn, is tolerably straight. The familiar diagrams are here: the three rays of radium in a magnetic field, the oil-drop setup, the Bohr-Sommerfeld rosettes, and the little white and black nucleons grouped into triangles and hexagons for various light isotopes.

The book is filled with staccato facts: the names of firms, Congressmen, diplomats, and philosophers may jostle one another on any page. The sentences are simple and short. The paragraphs are short, too. There are plenty of numbers, such as the 200 ships of the Bikini test task force, the 4900 tons of the big Berkeley cyclotron, and the gamma-ray wavelength of 0. 000,000,000,2 of a centimeter (*sic*).

The whole effect is like reading a newspaper account of some public event you have personally attended. There are no real blunders, or only a few, but the flavor is gone. Dietz is an agreeable writer and an earnest and informed man—better informed than most of us—but this quick excursion is somehow unconvincing and flat. Packed with facts and nobly trying to cope with abstractions, yet the book somehow belies the nature of physics and its history as a physicist knows it.

It would be proper for me to cite any real sins of the book, which was evidently unsatisfying to me. I cannot. They are not there. But it seems clear that this rapid pastiche, full of immediacy and yet packed with forgotten history (who remembers Nicholas of Autrucia or Orme Masson?), is not what popular science ought to be. It is wise to give an example: the Michelson-Morley experiment is described in two lines, within a two-page exposition of special relativity. But the full names and universities of Michelson and Morley are given. Within the severe limitations of this kind of emphasis, Dietz has done a wholly competent job.

What is the audience for such a book? Perhaps the eager 12-year-olds will devour it for its heady flavor of facts. Perhaps it will serve to acquaint some people with the bones of atomic science, or as a desk reference for others. But it lies outside the tradition of Huxley or Hecht, of most scientific popularizers of great success. It informs compactly, it explains clearly enough, but somehow it does not illuminate.

P. MORRISON

Department of Physics, Cornell University

Art in Science: A Portfolio of 32 Paintings, Drawings, and Photographs from Scientific American. Simon and Schuster, New York, 1954. $6.

THESE plates, 26 of which are in color, have been selected from illustrations that appeared on the cover and text pages of various issues of the *Scientific American*. Each plate is separately and beautifully reproduced on paper of fine quality, 28 by 33 cm. The plates are supplied in a cardboard box and are unbound. Accompanying each plate is an unattached page containing an explanatory paragraph. Among the 32 topics pictured are "Crystals and electricity," "Paleolithic art," "Automatic control," "Death of a tarantula," "Jelly fish" (lithographs from Ernst Haeckel), "Radiation from a reactor," "Fertilization of flowers," and "Scintillation counters." There is an introductory essay on the interrelations of art and science by György Kepes, professor of visual design, Massachusetts Institute of Technology.

DUANE ROLLER

Ramo-Wooldridge Corporation

Margins of the Sea. Maurice Burton. Harper, New York, 1954. 212 pp. Illus. $3.

IF Maurice Burton had any particular audience in mind for his book it was one of curious nonbiologists. Its theme is the seashore as a rigorous testing ground for animal emergence onto land. Such an idea, if not part and parcel of a work on the more general aspects of evolution, requires many asides into related fields of biology, especially if no or little biological knowledge is presumed on the part of the reader.

These excursions—on mitosis, on restrictive specialization, on anthropomorphic terminology in the description of animal behavior and others—break the continuity of the book. This will probably be more irksome to the biologist who seeks in it arguments in support of the author's thesis than to the lay reader. The bulk of the book comprises a number of chapters on invertebrate natural history. Often, as for instance in the chap-

ter on sponges or on the sea anemone, Burton's pleasure in observations and his keen interest and insight shine through the descriptions. But at other times the well-chosen phrases and flawless descriptive writing, which are an attribute of the entire book, dwell on some points too long. The problem of humanizing invertebrate animal behavior in particular seems to intrigue the author.

Burton repeatedly discusses vitalistic and mechanistic concepts of life. There and in other parts of the book he talks about a number of interesting ideas, such as the similarity between animal structures and human inventions, the rhythmic activity of animals, its nature and its apparent ubiquity as an attribute of living organisms.

There are many often quite sweeping generalizations. Some of them, such as the increased complexity of terrestrial over aquatic organisms, might well have received more elaborate qualifications.

A reader who is fond of well-chosen explanations of scientific facts in familiar human terms cannot fail to derive some pleasure from Burton's excellence in this respect. The figures are well drawn and add a good deal, even to the extent of suggesting the shortening of some descriptive passages to which they refer. I am certain that anyone who reads the book attentively would have welcomed citations that are more elaborate than the mere mentioning of a name; or perhaps a full bibliography would have been preferable.

JOHN E. BARDACH
Department of Fisheries, University of Michigan

Modern Learning Theory. A critical analysis of five examples. W. K. Estes, S. Koch, K. MacCorquodale, P. E. Meehl, C. G. Mueller, W. N. Schoenfeld, and W. S. Verplanck. Appleton-Century-Crofts, New York, 1954. xv + 379 pp. $5.

THIS is a collection of five separate articles on five theories of learning—those most conspicuous and influential in current American psychology. The space devoted to each follows a fairly neat Zipf curve. Hull's theory occupies half of the book, Tolman's half of what is left, and so on through the theories of Skinner, Lewin, and Guthrie.

Although this book deals with a somewhat specialized branch of psychology, it has at least two claims on the attention of other scientists; it is one outcome of a novel "experiment" in the furthering of scientific competence, and it has as much to do, in some respects, with the logic of science as with the content of theories of learning.

In the introduction, Poffenberger stresses the pedagogic experiment of which this book is, more or less, an incidental outcome. In this venture, the seven authors were subsidized during a summer conference at Dartmouth College. This group had already spent quite some time together, at their own expense, discussing theories of learning. The Social Science Research Council took the initiative in financing them for one summer, hoping thereby to provide the time and opportunity for the young men to advance their interest and ability in research. This book is an afterthought, and apparently we are to read it, not to find out about the status of learning theory in mid-century, but to decide how well the young men made out.

Modern Learning Theory is clearly an important contribution to a specialized field, but it is hard to know just how much the conference helped. There is no *internal* evidence that one author influenced another. There are few cross references from one chapter to another. The thing that one might expect such a conference to promote—a comparison of various approaches to common problems—is almost studiously avoided. There is not even a subject index by which the reader can make such a comparison for himself.

The book deals only incidentally with content of learning theory. The emphasis is upon the logical precision of the statements and not upon what is said. Each theory is examined "for internal consistency and the extent to which it satisfies the logic of science." From the logicians listed (Carnap, Feigl), we may infer that *the* logic of science is to be that of the Vienna Circle. But there is no clear-cut statement on this point, nor is there any discussion of the advantages of this approach.

Koch's essay comprises half of the book and is concerned almost exclusively with an evaluation of the adequacy of Hull's theory in the light of Hull's stated aims. Offhand, this seems to be a peculiar criterion. In considering the adequacy of Newtonian theory, for instance, who stops to think about Newton's stated aims? In evaluating the 1943 Principles, moreover, Koch uses as his only guide the 1943 statement of aims, with all their excesses. He deliberately rejects Hull's 1947 reinterpretation of the 1943 statement. This *ad hominem* approach and captious tone, joined with the difficult prose, can make for extremely irksome reading. Koch suggests that he may be accused of having done a "nasty thing." I, no Hullian, would not be surprised. In the realm of content, Koch shows that the important Hullian revisions came chiefly from the demands of quantification. He also contends that Hull has essentially ceased to be a reinforcement theorist.

MacCorquodale and Meehl, in their essay on Tolman, continue the emphasis on the logic of science. They are also concerned, however, with the agreement between theory and data. There is an important extension of the authors' earlier attempt to formalize Tolman's system.

In Verplanck's chapter on Skinner, the pure stream of logic is contaminated by some 10 pages of straight exposition. Verplanck does what he can to establish the theoretical position of one who rejects most of the ordinary notions of theory.

The clearest account of the purposes and basic approaches of the conference is given in Estes' chapter on Lewin. The intensive and persuasive analysis of Lewinian theory is rather devastating. One hopes that the Lewinians will produce a champion incisive enough to carry on the discussion at the level Estes has set.

Mueller and Schoenfeld quote generous quantities of Guthrie's lucid prose and thus bring the ordinary

psychologist back into familiar territory. This last chapter would be a good starting point for many psychologists. The authors smuggle in (and apologize for) some important comments on the content of learning theory. In an essay on the formal aspects of theory, one is surprised at the relative neglect of Voeks' formalization.

Briefly, then, this book is a must for those interested in the logical adequacy of contemporary theories of learning. It also has an important, if specialized, bearing on learning theories in general and on the problem of theory construction in many different fields.

J. M. STEPHENS
Departments of Education and Psychology, Johns Hopkins University

The Study of Personality. A book of readings. Compiled by Howard Brand. Wiley, New York; Chapman & Hall, London, 1954. xvi + 581 pp. Illus. $6.

HERE is an eclectic and, in the main, well-selected body of readings designed to supplement textbooks in the area of personality or even to stand alone as readings in a course on personality. For purposes of presentation, the readings have been grouped under three headings—theory, methods, and problems—and each heading is preceded by a general introduction prepared by Brand.

An effort has been made in this compilation to improve upon similar readings previously available. This has taken the direction of drawing, in each of the three sections, upon materials from clinical, experimental, and social psychology as well as from anthropology and sociology. The result is a breadth of coverage not heretofore attained. However, it suffers somewhat from a diversity of vocabulary and terminology. For the student who wishes a large view of the field, these readings are of indisputable value, and the introductions provided by Brand serve in some degree to bind the diverse contents together. As an effort to transcend the limits of nominal academic disciplines, this work must be viewed as a success.

ROBERT H. KNAPP
Department of Psychology, Wesleyan University

Sailing Aerodynamics. John Morwood. Philosophical Library, New York, 1954. 124 pp. Illus. $7.50.

THIS little book purports to introduce small-boat sailors to the aerodynamics of sails. After an introduction, it is divided into 13 chapters. Of these, the last five chapters, almost one-half of the book, are devoted to interpretation, inventions of new rigs, sailing tactics, and winds—undoubtedly interesting to the yachtsman but hardly "aerodynamics."

The portion that is strictly aerodynamics introduces the reader to the concepts of air pressures, forces, and force coefficients on sails and wing sections. Then follows a discussion of the resolution of the air force into thrust and side-force coefficients and the relationship between these and the resistance and lateral force of the boat hull in the water. This treatment is good, correct, and well explained, so that sailors without a technical background, yet intelligent, should understand it.

The relationships between the speed and heading of the boat, the course, real and apparent wind velocities, and directions are not well explained. The addition of one or two simple diagrams would have been an improvement. The choice of obsolete airfoil data and pressure distributions from early work by Eiffel is unfortunate, even though the questionable accuracy of the data does not detract from the usefulness of the presentation. Later statements that the USATS 10 appears to be the best all-round airfoil for sails continues the impression of antiquity.

American small-boat sailors will notice differences in nomenclature; for example, "Bermudian rig" proves to be the common jib-mainsail arrangement. Most of the figures are clear, but some are confused, and the standard of draftmanship is very poor when the price of the book is considered.

SHATSWELL OBER
Aeronautical Engineering Department, Massachusetts Institute of Technology

Practical Clinical Biochemistry. Harold Varley. Interscience, New York; Heinemann, London, 1954. vii + 551 pp. Illus. $6.50.

THE author, who is a biochemist for the Manchester Royal Infirmary and lecturer in clinical pathology at Manchester University, wrote this work as a practical survey of the methods used in clinical biochemistry. It contains a number of alternate methods for substances usually determined in blood, urine, and spinal fluid in the laboratory of a large hospital as well as procedures usually carried out only in special or research laboratories. The techniques are clearly written and the precautions necessary for satisfactory results are stressed.

The number of alternate procedures given for a single substance (seven for sugar) indicates either a lack of discrimination in the choice of method or that there are more methods in current use in England than there are in the United States. Some of the methods are more than 25 years old and a number of them would be unfamiliar to American workers. On the other hand, many very modern procedures are outlined. The separation and identification of reducing substances in urine by paper chromatography and the separation of plasma proteins by paper electrophoresis are two examples.

There are chapters on the liver, kidneys, gastric and pancreatic functions, spinal fluid, stones, milk, drugs and poisons, hormones, and basal metabolism. Short summaries of findings in health and disease add to the usefulness of this volume. It should be valuable as a reference for anyone working in this field.

MARIE A. ANDERSCH
Division of Clinical Pathology, Department of Medicine, University of Maryland Medical School

Our American Weather. George H. T. Kimble. McGraw-Hill, New York–London, 1955. xv+322 pp. Illus. $4.75.

RECENTLY there has been no shortage of books about meteorology or about the weather, but this one is noteworthy because of its original organization. It is, in fact, an educated almanac, with 12 chapters named for the 12 months of the year and describes the unfolding weather of the year. Of course, the book cannot detail the varied weather of the whole country, nor is it a weather diary of any one place. Instead, it comprises innumerable short essays that bring together subjects that are appropriate for the various months. For example, here are the subjects that fall into the January basket: "Unseasonable weather," "January thaw," "Cold waves," "How cold can it get?" "It's not the cold, it's the windchill!" "When is midwinter?" "The ice storm," "The glaze resistance of trees," and "Life begins at forty below—for those that like it!"

The author is an Englishman who has been in North America less than a decade—about 4 years in Montreal and the same time in the vicinity of New York. Therefore, he has a limited personal acquaintance with our American weather. However, his vast understanding of meteorology and his knowledge of English weather, to which he frequently contrasts our own, more than make up for this deficiency. He has written an exceedingly interesting book. I believe that the residents of Key West and San Diego will enjoy it thoroughly, even though they will never see or experience many of the things that he has described.

C. W. THORNTHWAITE
Laboratory of Climatology, Johns Hopkins University

Elements of Statistical Mechanics. D. ter Haar. Rinehart, New York, 1954. xix+468 pp. Illus. $8.50.

IN many ways this is a good book. It contains a number of features that, in general, writers of advanced textbooks might well consider incorporating into their works. One feature is the fine set of bibliographic notes devoted to further developments not fitting neatly into the earlier framework that are placed at the end of each of its 15 chapters and six appendixes (practically chapters in themselves). These notes not only constitute a fairly complete set of references to the literature of the subjects discussed but also give a desirable historical perspective. The text is generally stimulating, will whet the curiosity of the able student, and, through the notes (and additional references in the text), will help him satisfy it. Other attractive features are the modern tone of the discussions, the seven-page glossary of symbols with page references to their definitions and principal occurrence, the detailed name and subject indexes, the attention given to the foundations of the subject, and the generally clear and concise discussions.

The book is divided into four parts. Part A, the statistics of independent particles (four chapters), covers a bit of kinetic theory (introducing the famous H-theorem discussed at length in appendix I), the Maxwell-Boltzmann distribution, the Fermi-Dirac and Bose-Einstein distributions, and some simple applications (Planck radiation law, the perfect gas in the three cases, rigid rotator and specific heat of hydrogen, Sackur-Tetrode equation, phase integrals, partition functions, and the connection between thermodynamics and statistical mechanics). Part A is on a much more elementary level than the rest of the book, presupposing little knowlege of quantum mechanics.

Part B, ensemble theory, devotes a chapter to each of the following topics: petit ensembles (micro- and macrocanonical), classical grand ensembles, and ensembles in quantum statistics. This last chapter, based on the quantum-mechanical density matrix, will be beyond readers who lack familiarity with quantum theory. Fluctuations in the three statistics are discussed by ensemble methods.

Part C, applications, consists of eight chapters concerned with the equation of state (supplemented by appendix V on intermolecular forces), condensation phenomena, electron theory of metals, semiconductors, cooperative phenomena, statistical methods in nuclear physics, equilibrium theory of the origin of the elements, and the statistical theory of rubber elasticity. Most of these chapters are short, except for those on equation of state and cooperative phenomena; the last chapter in this part is almost a review article on theories in the field rather than an introductory discussion.

Part D, appendixes, in addition to appendixes I and V already mentioned, has others on irreversible processes, the third law of thermodynamics, the Darwin-Fowler method, relativistic statistics, a table of constants, and a mathematical appendix (steepest descent, Stirling formula, and Lagrange multipliers).

My main criticisms of this book are that (i) many extremely important topics have been omitted, (ii) the applications selected give a kaleidoscopic succession of impressions in which much desirable unity is obscured and (iii) too few comparisons between theory and experiment are made. The quasi-chemical method is discussed in its application to order-disorder, but no mention is made of its applicability to theory of solutions. No discussion is given of chemical equilibrium, although similar considerations are invoked when the origin of the elements is discussed. Nothing is said of dissociation, liquids, and ionic equilibria, and hardly anything is said of the statistical mechanics of gases. Physical chemists, chemical physicists, and others who otherwise might have found the book of great value will thus look to other sources for treatments of problems of most interest to them. Some of the chapters on applications are so short that one has to go elsewhere to come to grips with the subject, or else they are so specialized that they are little more than a summary of a few papers.

The book tends to fill a gap between big tomes, such as those of Fowler and Tolman, and little ones, such as Rushbrooke's, discussing as it does, foundations, techniques, and applications within a reasonable compass. In my opinion, its value would be enhanced if problems had been included so that the student could

apply the techniques to obtain results and, thus, more easily see the power and wide applicability of the techniques. A judicious selection of sequences of related problems could well meet many of these criticisms. The book should become popular as a textbook and reference for graduate physics courses in statistical mechanics.

JEROME ROTHSTEIN
Signal Corps Engineering Laboratories

Numbers: Fun and Facts. J. Newton Friend. Scribner's, New York, 1954. xi + 208 pp. Illus. $2.75.

Mathematical Puzzles and Pastimes. Aaron Bakst. Van Nostrand, New York–Toronto; Macmillan, London, 1954. vi + 206 pp. Illus. $3.75.

THESE two books overlap in several areas while maintaining their individual approach. The title of the first, *Numbers: Fun and Facts,* gives an accurate description of its contents. Friend gives a historical sketch on the origin of numbers, together with many interesting traditions and superstitions associated with individual numbers ranging from 1 to 1 billion. Numbers with interesting and curious mathematical properties are discussed at some length. A large section of problems, some of a trivial nature and some of considerable difficulty, rounds out the book.

The second book, *Mathematical Puzzles and Pastimes,* also contains a rather large selection of problems as well as some discussion of mathematically interesting numbers. Number systems are discussed in some detail, but the sexadecimal system is barely mentioned. This is unfortunate, since numbers to the base 16 are in constant use in many digital computer installations. Bakst discusses general principles that are used in solving various mathematical problems, both numerical and geometric. A perpetual calendar and an Easter date calendar are a bonus feature of this book. Both books have much to interest anyone who delights in numbers, but unfortunately several false statements, in addition to the usual typographic errors, appear.

PHILIP RABINOWITZ
National Bureau of Standards

Elements of Algebra. Howard Levi. Chelsea, New York, 1954. 160 pp. $3.25.

THIS textbook, which is for use in a course in general studies, is quite a departure from the usual approach to algebra. Although the author asserts that no previous knowledge of algebra is presupposed, but only curiosity, it is important that the student have some mathematical maturity. The material, or at least a part of it, seems more of an introduction to what is usually called modern algebra.

Levi points out many of the pitfalls of the student who has only inadequate concepts and ideas of the use and manipulation of the symbols. The material is developed logically, starting first with sets and cardinal numbers, and followed by the laws of addition and multiplication. By use of these laws, expressions such as monomials and polynomials, are introduced.

The development of integers is excellent, and also, in sequence, rationals and irrationals. Then the treatment of real numbers and the number system in general follow easily. The material on order is the type that is usually encountered and is important because it points out that usually accepted concepts can often be logically developed.

There are two rather glaring weaknesses in this book. The treatment of equations leaves much to be desired, and the introduction of groups, rings, and fields should either be omitted or discussed in more detail. Otherwise the book is certainly suitable for the purposes set forth in the preface.

HERBERT L. LEE
Department of Mathematics, University of Tennessee

Pygmies and Dream Giants. Kilton Stewart. Norton, New York, 1954. 295 pp. $3.75.

HERE is a rare book, recording modern psychic tests, dream interpretations, and personal adventures among the primitive peoples of the northern island of Luzon, the Philippines. Stewart has written an account of his understanding of, and wild experiences among, strange tribes of pygmies, including the Ifugao, Ilongots, Kalingas, Kankanai, and Bontocs.

His chief interest centers in the psychological understanding and interpretation of his willing and spontaneous "friends" who revealed their dreams, spirit possession, and mental ways to him. Stewart states that his purpose

> . . . was to determine as best I could what kind of native intelligence the people of these nonliterate societies had in the beginning, and then to find out what kind of mind was built up on that basic intelligence by the group processes in which they found themselves involved, especially as revealed by their dreams, visions and ceremonial procedures. (p. 25)

Armed only with necessary, useful medicines and a minimum of food and water, but with a battery of tests (the maze, draw a man, and emotional response) and a native guide and interpreter, Stewart set out to find scientific and romantic adventure. His account is filled with fascinating thrills.

Living with the native groups, he participated in their ceremonies and other phases of their daily lives and shared their food, their ways, and their thoughts. The resulting description of these people holds much of a solid ethnological nature. As the result of his labors, weird experiences, and capital luck, Stewart believes that he has an understanding of

> . . . this universal man . . . who is the same as all other men in the sight of God and law . . . and to determine what the various (and different) cultures do to this universal individual. (p. 26)

Although the separate chapters do bring the reader the personal feelings of the author as he lived among these little-known and little-studied societies, I find

the interpretations of the scientific data disjointed and abrupt. The interesting last chapter, "Universal man," summarizes well the data compiled by Stewart and enables the lay reader to comprehend something of, and to agree with, the "vastness and intricacy of the kingdom inside man's skin—the universe which [is] man himself" (p. 271).

The title comes from Stewart's belief that all of us have giant selves, capable, under the proper sociocultural environment, of vast achievements.

CHARLES E. SNOW
Department of Anthropology, University of Kentucky

Flash! Seeing the unseen by ultrahigh-speed photography. Harold E. Edgerton and James R. Killian, Jr. Branford, Boston, ed. 2, 1954. 215 pp. Illus. $6.50.

THIS second edition brings up to date a technique that was in its infancy in 1939 when the first edition was published but since then has grown rapidly in the development of new equipment and its uses.

This is a new book in which the science of electronics joins hands with photography to observe the commonplace revealing that which had never been seen before. One is greatly impressed with the symmetry and balance of arrested motion. The patterns of multiple-exposure photographs of moving objects show the orderliness of nature. This new tool in the hands of a scientist permits a closer study of kinetics, and the measurement of a new dimension.

Photographs by the author and selections from the works of some of America's leading photographers add much to the pictorial value of this book. The part labeled "Supplementary data" is easy reading of the more technical phases of electronic flash.

Written by the leading authority in this field, it is interesting to the layman and satisfying to the more technical minded. It is a must for those interested in flash photography.

ELBRIDGE C. PURDY
U. S. Department of Agriculture Graduate School

American Men of Science. vol. I, *The Physical Sciences.* A biographical directory. Jaques Cattell, Ed. Science Press, Lancaster, Pa. and Bowker, New York, ed. 9, 1955. 2180 pp. $20.

A NEW edition of *American Men of Science* is always an important event and a welcome addition to a scientist's bookshelf. As the scientific population grows, the necessity for this biographic reference work increases; since the 8th edition appeared in 1949, the number of names included has increased from 50,000 to 90,000. The increase convinced the publishers that a single volume was no longer practicable. In splitting 90,000 names into separate volumes, the publishers had to choose between making the division alphabetically and making it along subject-matter lines. They chose the latter course.

Volume I includes physical scientists, volume 2 (fall 1955) will include biological scientists, and volume 3 (spring 1956) will include social scientists. Users whose interests are largely confined to getting information about persons in a particular field, such as geology or mathematics, will find this arrangement convenient and will save money by buying only one volume.

There are, however, major disadvantages to the volume separation. The question of where to include biochemists and biophysicists illustrates the fact that not all scientists can be classified neatly into one of three pigeonholes. Each member of these groups was given his choice of a listing in volume 1 or volume 2. Some chose one way; some, the other. This made it necessary to list practically all names in both volumes, with a biography in one and cross reference in the other. The cross-reference feature is also used in the inclusion of some names in the new edition with a reference to the 8th edition for detailed information. The book is therefore less handy than an alphabetic division would have been for users who are interested in all fields of science or in those fields that do not fit neatly into the current arrangement.—D. W.

Freaks and Marvels of Insect Life. Harold Bastin. A. A. Wyn, New York, 1954. Illus. + plates. $3.75.

THIS book is a popular, readable account of a number of phases of entomology, as the following randomly selected chapter titles suggest: "Eggs and egg-laying," "Leaf folders and rollers," "Oak apples and other galls," "Insects as flying-machines," "Camouflaged insects," "What mimicry means," "Insects in the water," and "Insects and flowers."

The title is misleading as there do not seem to be any "freaks" described, and the emphasis is on the remarkable features of insect life which are commonplace to an entomologist but little known to the layman. However, for the most part accurate accounts of many oddities of insects and their behavior are presented. Technical terms are almost completely avoided. The viewpoint is British but many unusual insects from other countries are illustrated or described. The plates are reproduced in black and white; many are photographed in nature, others are posed.

CHARLES D. MICHENER
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Flowers of the South. Native and exotic. Wilhelmina F. Greene and Hugo L. Blomquist. Univ. of North Carolina Press, Chapel Hill, 1953. xiv + 208 pp. Illus. + plates. $5.

IN the confines of this attractively compiled book, more than 560 flowers are listed, described, identified by both common and botanical names, and excellently illustrated, some in color plates. The book is divided into two sections: the first dealing with native wild flowers, and the second with the exotic or cultivated varieties. The fact that the book is concerned only with flowers found in the South will not preclude enjoyment by those interested in floral information and illustration.

Books Reviewed in SCIENCE

1 April

The Vitamins: Chemistry Physiology, Pathology, vols. I and II, W. H. Sebrell, Jr., and Robert S. Harris, Eds. (Academic Press). Reviewed by H. E. Sauberlich.

Zoology, Clarence J. and Marie L. Goodnight (Mosby). Reviewed by M. Bates.

Streams, Lakes, Ponds, Robert E. Coker (Univ. of North Carolina Press). Reviewed by J. W. Hedgpeth.

Trigonometry, Elbridge P. Vance (Addison-Wesley). Reviewed by E. A. Nordhaus.

Tables of Integral Transforms, vol. II, A. Erdélyi, Ed. (McGraw-Hill). Reviewed by R. P. Boas, Jr.

Monomolecular Layers, Harry Sobotka, Ed. (AAAS). Reviewed by H. A. Frediani.

Das Glas im chemischen Laboratorium, Fritz Friedrichs (Springer). Reviewed by W. A. Weyl.

Practical Physiological Chemistry, Philip B. Hawk, Bernard L. Oser, and William H. Summerson (Blakiston Div., McGraw-Hill). Reviewed by F. R. Blood.

8 April

Lehrbuch der Paläobotanik, Walter Gothan and Hermann Weyland (Akademie-Verlag). Reviewed by C. A. Arnold.

Organic Syntheses, vol. 34, William S. Johnson, Ed. (Wiley; Chapman & Hall). Reviewed by I. M. Hunsberger.

Chemical Pathways of Metabolism, vol. II, David M. Greenberg, Ed. (Academic Press.) Reviewed by R. W. Jackson.

An Outline of Developmental Physiology, Chr. P. Raven (McGraw-Hill; Pergamon Press). Reviewed by J. S. Nicholas.

Elements of Food Engineering. vol. 3, *Unit Operations*, pt. 2, Milton E. Parker (Reinhold). Reviewed by B. E. Proctor.

New Instrumental Methods in Electrochemistry, Paul Delahay (Interscience). Reviewed by T. De Vries.

Water Supply and Waste-Water Disposal, Gordon Maskew Fair and John Charles Geyer (Wiley; Chapman & Hall). Reviewed by A. M. Buswell.

15 April

The Fifth Amendment Today, Erwin N. Griswold (Harvard Univ. Press). Reviewed by G. W. Beadle.

A History of Technology vol. I, *From Early Times to Fall of Ancient Empires*, Charles Singer, *et al.*, Eds. (Oxford Univ. Press). Reviewed by I. B. Cohen.

The Scientific Revolution, 1500–1800, A. R. Hall (Longmans, Green). Reviewed by R. Multhauf.

American Men of Science. vol. I, *The Physical Sciences*, Jaques Cattell, Ed. (Science Press).

Composition of Scientific Words, Roland Wilbur Brown (U.S. National Museum). Reviewed by J. W. Hedgpeth.

An Autumn Gleaning, Henry H. Dale (Interscience; Pergamon Press). Reviewed by S. Brody.

Concepts of Space, Max Jammer (Harvard Univ. Press). Reviewed by J. O. Hirschfelder.

Advances in Electronics and Electron Physics, vol. VI, L. Marton, Ed. (Academic Press). Reviewed by C. Kittel.

High-Energy Accelerators, M. Stanley Livingston (Interscience). Reviewed by W. K. H. Panofsky.

Sonics, Theodor F. Heuter and Richard H. Bolt (Wiley, Chapman & Hall). W. L. Nyborg.

Existence Theorems for Ordinary Differential Equations, Francis J. Murray and Kenneth S. Miller (New York Univ. Press). Reviewed by C. P. Wells.

Higher Algebra, vols. I and II, Helmut Hasse (Ungar); *Exercises to Higher Algebra*, Helmut Hasse and Walter Klobe (Ungar). Reviewed by H. Eves.

Macroscopic Theory of Superfluid Helium, vol. II of *Superfluids*, the late Fritz London (Wiley; Chapman & Hall). Reviewed by C. F. Squire.

Organic Chemistry, Lewis F. Hatch (McGraw-Hill). Reviewed by E. E. Van Tamelen.

Electrometric pH Determinations, Roger G. Bates (Wiley; Chapman & Hall). Reviewed by J. J. Lingane.

Glutathione, S. Colowick *et al.*, Eds. (Academic Press). Reviewed by M. H. Adams.

Micro and Semimicro Methods, Nicholas D. Cheronis. vol. VI of *Technique of Organic Chemistry*, Arnold Weissberger, Ed. (Interscience). Reviewed by E. B. Reid.

Principles of Biochemistry, Abraham White, Philip Handler, Emil L. Smith, and DeWitt Stetten, Jr. (McGraw-Hill). Reviewed by M. Levy.

Physical Measurements in Gas Dynamics and Combustion, vol. IX of *High Speed Aerodynamics and Jet Propulsion*. pt. 1, R. W. Ladenburg; pt. 2, B. Lewis, R. N. Pease, and H. S. Taylor, Eds. (Princeton Univ. Press). Reviewed by G. B. Kistiakowsky.

Genetic Homeostasis, I. Michael Lerner (Wiley; Oliver & Boyd). Reviewed by B. Wallace.

The Physiology of Insect Metamorphosis, V. B. Wigglesworth (Cambridge Univ. Press). Reviewed by C. M. Williams.

Contributions to Embryology, vol. 35 (Carnegie Institution of Washington). Reviewed by C. L. Davis.

The Genetics of Paramecium aurelia, G. H. Beale (Cambridge Univ. Press). Reviewed by D. L. Nanney.

Recent Developments in Cell Physiology, J. A. Kitching, Ed. (Academic Press; Butterworths). Reviewed by D. Mazia.

Insects of Micronesia. vol. I, *Introduction*, J. Linsey Gressitt (Bernice P. Bishop Museum). Reviewed by F. R. Fosberg.

Die Evolution der Organismen, pts. I–III, Gerhard Heberer, Ed., (Fischer). Reviewed by E. Mayr.

Nuclear Geology, Henry Faul, Ed. (Wiley; Chapman & Hall). Reviewed by E. Segrè.

Some Fundamentals of Petroleum Geology, G. D. Hobson (Oxford Univ. Press). Reviewed by P. W. Hughes.

Applied Geophysics in the Search for Minerals, A. S. Eve and D. A. Keys (Cambridge Univ. Press). Reviewed by L. B. Slichter.

Seismicity of the Earth and Associated Phenomena, B. Gutenberg and C. F. Richter (Princeton Univ. Press). Reviewed by F. Gassmann.

Climatic Atlas of the United States, Stephen Sargent Visher (Harvard Univ. Press). Reviewed by H. P. Bailey.

Handbook of Radiology, Russell H. Morgan and Kenneth E. Corrigan, Eds. (Year Book) Reviewed by R. H. Chamberlain.

Human Physiology, Bernardo A. Houssay, Juan T. Lewis, Oscar Orias, Eduardo Braun-Menendez, Enrique Hug, Virgilio G. Foglia, and Luis F. LeLoir (McGraw-Hill). Reviewed by A. J. Carlson.

British Pharmaceutical Codex, 1954 (Pharmaceutical Press). Reviewed by G. Sonnedecker.

Connective Tissue in Health and Disease, G. Asboe-Hansen, Ed. (Munksgaard). Reviewed by M. Schubert.

Biochemical Investigations in Diagnosis and Treatment, J. D. N. Nabarro (Little, Brown). Reviewed by O. Bodansky.

Pharmakotherapie des Fiebers und der fieberhaften Affektionen, R. Isenschmid, E. Glanzmann, H. Berger, and T. Gordonoff (Huber). Reviewed by G. Rosen.

Animal Agents and Vectors of Human Disease, Ernest Carroll Faust (Lea & Febiger). Reviewed by C. G. Huff.

Porphyrins, A. Vannotti (Hilger & Watts). Reviewed by S. Granick.

Perspectives in Physiology, Elza Vieth, Ed. (American Physiological Soc.). Reviewed by E. F. Adolph.

29 April

Optics, vol. IV, Arnold Sommerfeld (Academic Press). Reviewed by A. G. Shenstone.

The Psychology of Invention in the Mathematical Field, Jacques Hadamard (Dover). Reviewed by S. H. Gould.

The Theory of the Photographic Process, rev. ed., C. E. Kenneth Mees (Macmillan). Reviewed by L. E. Varden.

Principles of Geomorphology, William D. Thornbury (Wiley; Chapman & Hall). Reviewed by C. R. Warren.

The Alkaloids: Chemistry and Physiology, vol. IV, R. H. F. Manske and H. L. Holmes, Eds. (Academic Press). Reviewed by L. H. Small.

Organic Analysis, vols. I and II, John Mitchell *et al.*, Eds. (Interscience). Reviewed by L. Chalkley.

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Cultural Anthropology. An abridged revision of *Man and His Works.* Melville J. Herskovits. Knopf, New York 22, 1955. 569 pp. $5.

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Isotope Geology. Kalervo Rankama. McGraw-Hill, New York 36; Pergamon Press, London, 1955. 535 pp. $12.

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American Men of Science. vol. I, *Physical Sciences.* A biographical directory. Jaques Cattell, Ed. Science Press, Lancaster, Pa. and Bowker, New York 36, ed. 9, 1955. 2180 pp. $20.

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Outlines of Enzyme Chemistry. J. B. Neilands and Paul K. Stumpf. Wiley, New York 16; Chapman & Hall, London, 1955. 315 pp. $6.50.

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Art in Science. A portfolio of 32 paintings, drawings, and photographs from *Scientific American,* with an introductory essay on the interrelations of art and science by György Kepes. Simon and Schuster, New York, 1954. $6.

Culture and Human Fertility. A study of the relation of cultural conditions to fertility in non-industrial and transitional societies. Frank Lorimer. UNESCO, Paris, 1954 (Distr. by Columbia Univ. Press, New York 27). 514 pp. Paper, $4.50.

Advanced Mathematics for Engineers. H. W. Reddick and F. H. Miller; rev. by F. H. Miller. Wiley, New York 16; Chapman & Hall, London, ed. 3, 1955. 548 pp. $6.50.

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How to Solve Problems in General Chemistry. Joseph A. Babor and Chester B. Kremer. Crowell, New York 16, ed. 2, 1955. 152 pp. Paper, $1.25.

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***Thomas Bradwardine: His* Tractatus de Proportionibus.** Its Significance for the development of mathematical physics. Edited and trans. by H. Lamar Crosby, Jr. Univ. of Wisconsin Press, Madison, 1955. 203 pp. $3.50.

Further Contributions to the Solution of the Piltdown Problem. J. S. Weiner *et al.* Geological Ser., vol. 2, No. 6. British Museum (Natural History), London, 1955. 60 pp. Paper, £1.

Proto-Lima. A Middle period culture of Peru. A. L. Kroeber. Fieldiana: Anthropology, vol. 44, No. 1. Chicago Natural History Museum, Chicago, 1954. 157 pp. Paper, $4.

The Mongrillo Culture of Panama. vol. XLIX, No. 2, Papers of the Peabody Museum of Archaeology and Ethnology, Harvard Univ. Gordon R. Willey and Charles R. McGimsey. Appendix on *Archaeological Marine Shells,* Robert E. Greengo. The Museum, Cambridge 38, Mass., 1954. 158 pp. Paper, $4.65.

Chemistry and Chemical Technology of Cotton. Kyle Ward, Jr., Ed. Interscience, New York–London, 1955. 782 pp. $20.

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The Psychiatrist and the Dying Patient. K. R. Eissler. International Universities Press, New York 11, 1955. 338 pp. $5.

Mosquitoes. Their bionomics and relation to disease. William R. Horsfall. Ronald Press, New York 10, 1955. 723 pp. $16.

Laboratory Manual for Histology. J. F. Smithcors. Burgess, Minneapolis 15, 1954. 101 pp. Paper, $3.

Proceedings of the Conference on Auroral Physics. N. C. Gerson, T. J. Keneshea, and R. J. Donaldson, Jr., Eds. Geophysical Research Papers, No. 30. Sponsored by Dept. of Physics, Univ. of Western Ontario, and Geophysics Research Directorate, Air Force Cambridge Research Center, 1954 (Order from U.S. Dept. of Commerce, Office of Tech. Services, Washington 25). 450 pp.

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Abstracts of the Literature on Semiconducting and Luminescent Materials and Their Applications. 1953 issue. Compiled by Battelle Memorial Inst. Wiley, New York 16; Chapman & Hall, London, 1955. 169 pp. Paper, $5.

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Laboratory Explorations in General Zoology. Karl A. Stiles. Macmillan, New York 11, ed. 3, 1955. 291 pp. Paper, $3.75.

Insanity, Art, and Culture. Francis Reitman. Philosophical Library, New York, 1954. 111 pp. $3.75.

Grundriss der Allgemeinen Zoologie. Alfred Kuhn. Thieme, Stuttgart, Germany, ed. 11, 1955 (Order from Intercontinental Medical Book Corp., New York 16). 281 pp. $3.95.

Lectures on Partial Differential Equations. I. G. Petrovsky. Trans. by A. Shenitzer. Interscience, New York–London, Engl. ed. 1, 1954. 245 pp. $5.75.

An Introduction to Plant Taxonomy. George H. M. Lawrence. Macmillan, New York 11, 1955. 179 pp. $3.25.

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The Volcanic Rocks of the Ross Archipelago. W. Campbell Smith. British Antarctic ("Terra Nova") Expedition, 1910, Natural History Rpt., Geology, vol. II, No. 1. British Museum (Natural History), London, S.W.7, 1954. 107 pp. Paper, £3.

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Evolution of the Vertebrates. A history of the backboned animals through time. Edwin H. Colbert. Wiley, New York 16; Chapman & Hall, London, 1955. 479 pp. $8.95.

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(*Continued on page viii*)

LETTERS

An International Language?

Charles Whitmore [*Sci. Monthly* **80**, 185 (Mar. 1955)] expressed doubt that there is any strong demand for an international auxiliary language on the part of working scientists. In this connection one might point out that demand grows with supply. For example, the market for automobiles in 1905 was extremely limited.

As one engaged in industrial research, I can see possibilities of immense practical value in a universally used auxiliary language to facilitate the international flow of scientific and technologic information. Unfortunately, there is no way in which I can concretely express my demand for such a tool by, for example, subscribing to a foreign technical journal that publishes material in the field of my interest and prints an edition in an international language.

Unhappily, there appears to be a great practical barrier to the adoption of an international auxiliary language. This barrier consists of an over-all situation that does not permit the natural gradual concurrent growth of demand and supply as in the case of automobiles. Until an international language is widely applied it has little practical value, and this tends to hold back the development of an active demand that is necessary to get the language widely accepted in the first place. It is difficult to see how this vicious circle can be broken until enough people in the various fields of science and technology take the necessary forethought and deliberately carry an international language across this formidable barrier.

Not being a linguist, I am not in position to comment on the validity of Whitmore's remarks to the effect that much of Interlingua looks like Latin gone more or less wrong. I can testify, however, to the facts that Interlingua requires virtually no effort in the development of a workable knowledge of it, that the language has a comfortable familiarity to it, and that it appears to have the capacity to fill easily and efficiently a real communication need.

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I have no wish to prevent anyone from using Interlingua if he thinks it will be serviceable; but Arthur L. Mottet's letter merely points out the need of breaking the barrier to its more extensive use without showing how this can be done. No doubt supply grows with demand; but how great is the effective demand in this case?

The question of an international language has been under vigorous discussion for nearly 70 years, yet the state of affairs is now very much what it was at the outset, and the general publication of material in any such language seems as far off as ever, quite apart from the merits of any specific proposal. At present, I believe that the greatly increased cost of printing is a much greater obstacle to the diffusion of information than is the absence of an accepted international language, however close to the ideal any suggestion might be.

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Evolutionary Naturalism alias "Scientism"

I have read with much interest and some disagreement the article by H. R. Rasmusson on "The preacher talks to the man of science" [*Sci. Monthly* **79**, 392 (1954)]. The position expounded in it is one that is held by a sufficient number of scientists, so that its publication is fully justified. Yet it would be unfortunate to let the subject drop where Rasmusson leaves it.

The word *scientism* seems to be intended approximately as a disparaging nickname for evolutionary naturalism, perhaps widened to include a few additional slightly different philosophic patterns. Whatever name one gives it, this evolutionary naturalism is a movement that has been growing, deepening, and expanding in a healthy fashion for many years. Cardinal for it is the thesis that man's mental abilities are what they are in consequence of the natural selection they have undergone. In this manner man's ancestors have evolved and man has inherited (i) the power to *know* by way of observation and of critical, dispassionate review of what is observed, and (ii) the power to *orient his life* to his knowledge by virtue of his emotive and esthetic capabilities. Disagreements between evolutionary naturalism and its intuitional opponents center primarily about the criterions of knowledge. One should note in this connection Bentley Glass' terse critique of so-called "spiritual insight" [*Sci. Monthly* **79**, 188 (1954)].

Naturalism perceives a fertile source for defective philosophies in the human propensity for blurring and confusing the aforementioned two functions of objective knowledge and subjective orientation. Indeed, under traditional religious influence, whole libraries have been written in the effort to make this blurring complete. Paul Radin [*The World of Primitive Man* (1953), p. 48] comments:

> Few of us would seriously contend that an inward experience, the presence of an inward thrill, would suffice to establish the reality of the whole cultural background. Yet this is precisely what does happen in aboriginal cultures, particularly for the man of action. Why, so he would contend, should something affect him in this way, if it were not true? This is an argument well known, of course, among us too.

In the nature of things, evolutionary naturalism tends to develop and mature chiefly among specialists,

and nonspecialists are likely to miss the purport of what these specialists are working to accomplish. The most crucial of their current philosophic concerns are in the field of ethics. One may well refer here to C. H. Waddington's article in the book symposium entitled *Science and Ethics* (1942), and to Julian Huxley's book *Touchstone to Ethics* (1947). Literature previous to 1947 is well surveyed by Huxley. Of the more recent naturalistic books one might (among many others) cite *The Meaning of Evolution*, by Simpson (1950), and *From Fish to Philosopher*, by Homer W. Smith (1953).

As a development, this evolutionist form of naturalism is necessarily young, as young as modern biology. But it is deeply rooted in the past, its critique of the criterions of truth having an ancestry no less venerable than the jurisprudence of Rome. As early as 1883 Francis Galton (*Investigation of Human Faculties*, ed. 1) advanced the new synthesis by showing that within these criterions of truth, strictly scientific tests can be made far beyond the traditional limits of natural science, to some extent even in the zone that the theologians claim for their own.

What then of the bruited conflict between science and religion? By science I would understand what a person knows or reasonably believes through dispassionate appraisal of evidence. By religion I would understand the thought and emotive pattern through which he adjusts himself for the conduct of his life (whence every man above a moron has his religion). Out of these together come his practical ethics, or the guideposts for his daily behavior. If his religion, so understood, calls for beliefs different from those in his science, then there is indeed conflict. Unfortunately, this is a widespread condition today among persons only partly scientific. But if a person's religious patterns are based on what he believes dispassionately through evidence, such conflict is out of the question. For a person in this adjusted position the solemn warnings against "scientism" seem like summoning an empty epithet against a straw man.

ADDISON GULICK
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A Note for the Preacher

H. R. Rasmusson (*1*) suggests a distinction between scientist and religionist: the former somehow is supposed to be concerned with sense-impressions that "lead into an external world" and the latter is concerned with something else called "dimensions of spirit" in experience that "lead to an order of reality . . . God." Thus, much psychological work is ignored—perhaps because students of sense-impressions or perception no longer find such peculiar orders of reality in experience (*2*).

Undoubtedly physiological research is just beginning to supply some insights into how the brain works when an individual reports different kinds of experience. Some of the most interesting and thorough reports are those of Penfield at McGill: patients with their cortical tissue stimulated electrically during an operation may report experiencing specific past events, or sometimes what appears to be a generalized experience, or they may report experiences peculiar to that kind of activation (*3*).

The structures in the brain essential to consciousness are well established (*4*); research on the rhinencephalon and associated structures indicates they may be essential loci for emotional aspects of experience (*5*). Not that such research can explain yet specifically what is going on during a spiritual type of activity, but there is no good reason to suspect that this will present a greater problem than, say, what happens during various types of psychotic episodes—and the latter problem will soon be cracked if it is given the support it deserves. To imply that there are some special aspects of human experience protected from research or to pretend that scientists would seek understanding of the various human reactions to a sunset only in an analysis of light rays is to ignore some of the significant trends in modern science.

There is a variety of quotations from scientists one might use to offset those selected by Rasmusson. The one I think appropriate for this discussion comes from the witty W. S. McCulloch (*6*):

> So, to my mind Newton, Planck, and Jeans sin by introducing God as a sort of mind at large in the world to account for physical effects, like the action of gravity at a distance.

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References and Notes

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2. E. Brunswik, "The conceptual framework of psychology," in *Int. Encycl. Unified Sci.* vol. I, No. 10 (Univ. of Chicago Press, Chicago, 1952).
3. W. Penfield and H. Jasper, *Epilepsy and the Functional Anatomy of the Human Brain* (Little, Brown, Boston, 1954).
4. J. F. Delafresnaye, Ed., *Brain Mechanisms and Consciousness* (Thomas, Springfield, Ill., 1954).
5. K. H. Pribram and L. Kruger, *Ann. N.Y. Acad. Sci.* 58, art. 2, 109 (1954). An excellent discussion of some of the implications of animal and physiological research for the study of human emotions and taboos is given by D. O. Hebb and W. R. Thompson, in *Handbook of Social Psychology*, vol. I, G. Lindzey, Ed. (Addison-Wesley, Cambridge, 1954).
6. W. S. McCulloch, in *Cerebral Mechanisms in Behavior*, L. A. Jeffress, Ed. (Wiley, New York, 1951).

Rejoinder

After reading again my article, "The preacher talks to the man of science," I fail to understand how Addison Gulick can say that I use the word *scientism* as "a disparaging nickname for evolutionary naturalism." However, his note does illustrate very beautifully how

in the name of science a theory of life and morals is given the label of "science," hence "scientism."

In my article I said: "Scientism . . . is a cult that has made a religion out of science." It seeks to give to a theory of reality a standing other than a philosophy or a faith.

I do not wish to enter upon a controversy about the merits or demerits of evolutionary naturalism as such. What I do dispute is the position that Gulick takes that it has a standing in intellectual circles other than a philosophy, or a faith. Evolutionary naturalism is a philosophic interpretation of life and nature. To claim for it scientific verification is to be guilty of "scientism."

In the references suggested by Gulick, there are illustrations of this unscientific procedure and in particular in the writings of H. W. Smith, some of whose writing I have heard characterized as "arrogant." In this connection, I suggest another book for careful reading by Gulick, *The Moral Theory of Evolutionary Naturalism*, by William F. Quillian, Jr. [Yale University Press (1945)], which shows the inadequacy of a naturalistic ethic. He might profitably also read, ***Nature, Man, and God***, the great Gifford lectures, by William Temple [MacMillan Co. (1949)], particularly lecture VIII.

It should be clear in this discussion that the argument is not about the merits of a scientific theory of evolution but about a moral theory that rather dogmatically purports to be based on scientific facts and to wear the label "scientific."

Let it be taught by all means, but as a philosophic interpretation of life and nature, not as "science." Otherwise it is "scientism." Labeling it does not disparage the doctrine of evolutionary naturalism as a moral theory but as a moral theory falsely claiming to be "science."

H. C. Landsell's comments indicate more than anything else that "one man's speech is another man's jargon." However, I did not intend to imply in my article that "there are some special aspects of human experience protected from research," because I do not believe there should be protected areas marked "no trespassing." Nor would I "pretend" that physics is the only branch of science that can deal with "sunsets" or other aspects of human experience. Let all the sciences teach us all they can concerning *how* this and that takes place. Understanding the *how* does not invalidate the experience, nor does it make for a materialistic philosophy. My objection is to the scientist going beyond argue for his particular philosophy or to draw an interpretation from his knowledge that he forgets is a "faith."

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On "Validity of Test Items That Involve Finding a Pattern in Data"

Richard H. Lampkin's distrust of number series tests [*Sci. Monthly* **80,** 50 (Jan. 1955)] on the grounds that they have plural solutions deserves a second look. There is scarcely a natural phenomenon or a mathematical whodunit that does not have numerous *possible* solutions. The mark of the scientist is his ability to discover the simplest solution satisfying all the data. For example, it is quite possible, but very laborious, to write equations for the solar system with the earth as its center; but it is much easier, and therefore more scientific, to accept the sun as center. Again, it may be that the sun rises on Sunday because the cock crows, on Monday to dry the washing, on Tuesday to make the flowers grow, and so forth. Such reasons certainly are possible. They could be poetry or religion. But they are not science if they contain unnecessary frills.

Lou Bahm
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Lou Bahm seems to imply that number series test items are secure against the criticism of plural solutions, because the ability that scientific investigators display in discovering "the simplest solution satisfying all the data" can be used on the items as well. Rather than rehearse arguments already given, I wish to call attention to Philipp Frank's admirable discussion of simplicity as a criterion for acceptance of scientific theories. Frank discusses [*Sci. Monthly* **79,** 139 (1954)] at length the very decision between Ptolemaic and Copernican theories to which Bahm refers. Frank concludes that even for technologic purposes, application of the criterion of simplicity "does not actually lead unambiguously to a scientific theory."

I wish to acknowledge receipt of a stimulating letter [P. B. Diederich, Educational Testing Service (3 Feb. 1955)] much too long for publication here. One comment from it is that my alternative solutions are ingenious, but not one freshman in a thousand is capable of such solutions. It is true that some effort on my part was required to express the several schemes in mathematical form. But much less sophisticated expressions would suffice for a college freshman and are within his understanding. For example, scheme B can be expressed as: the numbers turn the corner at 8, go back down to 0 and repeat the cycle indefinitely; or, count by twos up and down between 0 and 8. For another example, scheme C can be expressed as: count by even numbers to 8, then by odd numbers to 7 and repeat the cycle indefinitely.

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Books Reviewed

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5–8. American Soc. for Pharmacology and Experimental Therapeutics, Iowa City, Iowa. (C. C. Pfeiffer, Dept. of Pharmacology, Emory Univ., Emory University, Ga.)

5–9. American Inst. of Biological Sciences, Michigan State College, East Lansing, Mich. (H. T. Cox, AIBS, 2000 P St., NW, Washington 6.)

5–9. Econometric Soc., Ann Arbor, Mich. (R. Ruggles, Box 1264, Yale Station, New Haven, Conn.)

7–9. American Soc. of Photogrammetry, Los Angeles, Calif. (C. E. Palmer, 1000 11 St., NW, Washington 1.)

9–10. Soc. of General Physiologists, Woods Hole, Mass. (J. B. Buck, National Institutes of Health, Bethesda 14, Md.)

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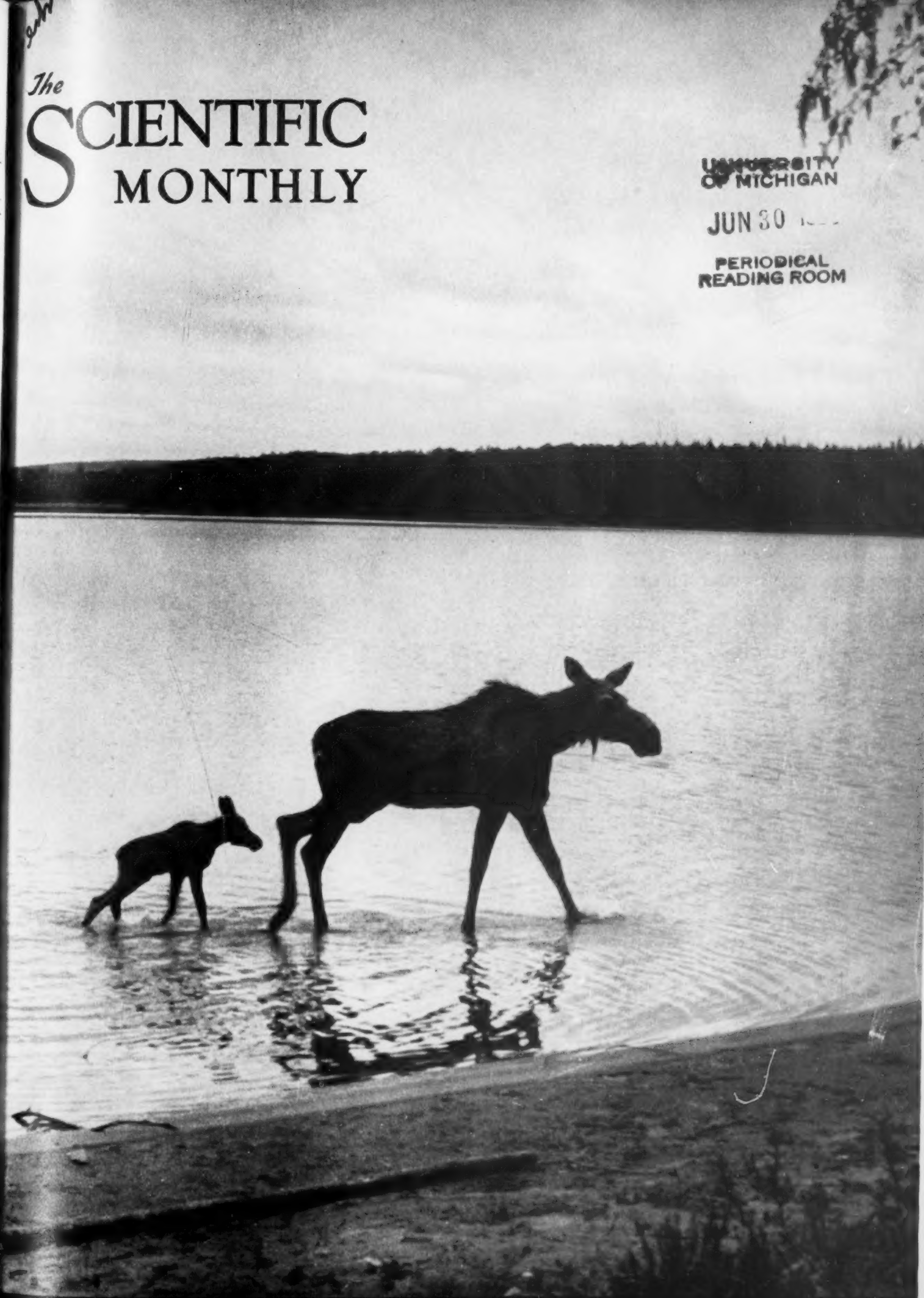

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4–11. International Cong. of Historical Sciences, 10th, Rome, Italy. (F. Chabod, Xe Congres International des Sciences Historiques, Université, Rome.)

5–6. American Political Science Assoc., Boulder, Colo. (H. C. Mansfield, Dept. of Political Science, Ohio State Univ., Columbus.)

5–8. American Soc. for Pharmacology and Experimental Therapeutics, Iowa City, Iowa. (C. C. Pfeiffer, Dept. of Pharmacology, Emory Univ., Emory University, Ga.)

5–9. American Inst. of Biological Sciences, Michigan State College, East Lansing, Mich. (H. T. Cox, AIBS, 2000 P St., NW, Washington 6.)

5–9. Econometric Soc., Ann Arbor, Mich. (R. Ruggles, Box 1264, Yale Station, New Haven, Conn.)

7–9. American Soc. of Photogrammetry, Los Angeles, Calif. (C. E. Palmer, 1000 11 St., NW, Washington 1.)

9–10. Soc. of General Physiologists, Woods Hole, Mass. (J. B. Buck, National Institutes of Health, Bethesda 14, Md.)

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